OFFICE OF THE MINISTER FOR SCIENCE

Report of the Committee on the Management and Control of Research and Development

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COMMITTEE ON THE MANAGEMENT AND CONTROL OF RESEARCH AND DEVELOPMENT

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* Sir Claude Gibb, K.B.E., F.R.S. was Chairman of the Committee until his death in January, 1959.

To the Lord President of the Council and Minister for Science

MY LORD:

I have the honour to submit to you the report of the Committee on the Management and Control of Research and Development which you set up in May, 1958 under the Chairmanship of Sir Claude Gibb, F.R.S. and with Sir Patrick Linstead, F.R.S., Sir Willis Jackson, F.R.S., Mr. A. A. Part and myself as members. Sir Claude died in the following January. You then appointed me in his place as Chairman, at the same time that you invited Sir George Edwards to join the Committee.

The sudden death of Sir Claude at an early stage of our deliberations was a great blow, and I should like to record, on behalf of the Committee, the benefit we derived not only from the general stimulus he provided, but also from his experience of the matters into which it has been our duty to enquire. If, as we hope, we succeeded in getting off to a good start, and in the right direction, it was largely due to his wisdom and sense of proportion.

I should also like to record the Committee's debt to Mr. D. Neville-Jones who served as our Secretary until the Autumn of 1959, and also to Mr. G. W. Robertson, by whom he was succeeded. Mr. Robertson has carried most of the burden of our enquiry, and only those who have had the experience of helping to draft a complex report of the kind with which we have been concerned will realise what we owe to his kindness, patience and skill.

S. ZUCKERMAN,
Chairman

5th July, 1961

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Introduction

CHAPTER I

SCOPE OF ENQUIRY AND DEFINITIONS

TERMS OF REFERENCE

1. We were set up in May 1958 by the Lord President of the Council, whose responsibility for the oversight of Government science later became that of the Minister for Science. Our terms of reference were :

> " To enquire into the techniques employed by Government Departments and other bodies wholly financed by the Exchequer for the management and control of research and development carried out by them or on their behalf, and to make recommendations."

2. These terms of reference cover all the research and development done by Government Departments ; by the Research Councils ; and by the Atomic Energy Authority. They also include the placing and control by these bodies of contracts for research and development carried out on their behalf by, say, industry or the universities. The subjects covered range widely—from agriculture to aircraft, from cancer to chemical engineering, from meteorology to mental health, from tanks to transatlantic cables. All this work costs the Government some £300 million per year and on it the Government itself employs over 11,000 qualified scientists and engineers.

3. Since work which is only partially financed by the Government is excluded from our enquiry, we have not been concerned with university projects such as the radio-telescope at Jodrell Bank, or with grants to university departments or individuals ; or with the industrial research associations that are grant-aided by the Department of Scientific and Industrial Research ; or with international organisations such as the European Organisation for Nuclear Research (C.E.R.N.). The management by industry and other agencies of any research and development contracts let to them by Government organisations is also outside our scope, as are the activities of the National Research Development Corporation, which is directly concerned with the financing, and not with the management, of development.

4. Our terms of reference focus on the techniques of management and control. From this we concluded that we were not expected to question directly the size or content of research and development programmes or the existing division of responsibility between the various organisations involved. But starting from a consideration of techniques of management, we have felt free to follow any argument to its conclusion even if that were to involve the consideration of some major change in, say, the inter-Service co-ordination of defence projects, or the structure of the Scientific Civil Service.

5. We have tried to discharge our task in strict accordance with our terms of reference and, therefore, within a framework that is set by the present pattern of scientific organisation. The kind of question we have been asking is whether the institutions with which we have been concerned can work

more effectively than they now do; whether the Government can get better value for the large sums of money which it makes available for research and development carried out on behalf of the armed services; and whether better management can increase the effectiveness of the scarce scientific and technical manpower engaged in the civil field. Our recommendations about such matters as the way subjects are chosen for research in the civil field, about the processing of operational requirements in the military sphere, and about the general need to encourage greater mobility among the members of the Scientific Civil Service, have thus been formulated in relation to an existing pattern of organisation.

The Main Issues

6. With so wide a field to cover we have been obliged to be selective. We tried at an early stage to identify the main issues, and for the most part, to concentrate our enquiries and our discussions on them.

7. We first noted that, within the total Government expenditure on research and development, defence predominates; it accounts for £240 million out of £286 million* in the Estimates for 1960–61 (see Table I, Chapter II). Moreover, a large part of the £240 million relates to a small number of projects for developing aircraft and guided weapons. Much concern has been expressed by Committees of the House of Commons and in the Press about projects whose completion has been greatly delayed and whose ultimate cost has borne little relation to the original estimates. We therefore put high on our agenda an enquiry into the techniques used in selecting and managing these big defence items. The main issue here is whether, in spite of the obvious difficulties of working near the frontiers of scientific knowledge, techniques can be evolved which can help the Government to get better results for its money. We believe they can, as we suggest in Chapters VII and VIII.

8. Although Government expenditure on the civil side, amounting to some £46 million a year (excluding the A.E.A.), is very much smaller than that devoted to defence, its efficient management is just as important. Government civil research and development contributes greatly both to the well-being of the people and to the economic strength of the nation, and is an essential supplement to the £200 million or so a year spent on research and development by industry itself. If the most fruitful projects are to be selected by Government research establishments, if they are to be efficiently managed, and if the results are to be applied in industry, special attention must be given to two matters in particular: the effective use of scarce manpower; and the links between Government research establishments on the one hand and industry, academic institutions and Government Departments on the other.

9. So far as manpower is concerned, the Government is the biggest single employer of scientists and technologists in the country, and three-fifths of the Scientific Officer Class of the Scientific Civil Service or its equivalents (that is, those with the highest qualifications) are employed on civil research and

* This figure excludes, for security reasons, expenditure by the Atomic Energy Authority but includes the cost of the National Institute for Research in Nuclear Science which is borne on the Authority's vote.

development. Are they employed to the best advantage? Do working conditions, the size and location of research establishments, and career arrangements produce the best practicable environment for successful work? How does the Scientific Civil Service compare in these respects with industry and the universities? The quality and morale of those who direct research and of the individual research workers are so important to efficiency that we devote a special Chapter (Chapter X) to the management of research staff.

10. A study of the relationship between Government research establishments and other organisations introduces another wide range of management problems. In industry most research establishments work for a single user or group of users, and are under the same control as their corresponding production and sales organisations. In civil research wholly financed by Government this is true only of the establishments controlled by the Atomic Energy Authority and by the Post Office. The other establishments are independently controlled and are concerned with more than one potential user. In these circumstances it becomes particularly important to ensure that Government research establishments are responsive to the needs of the users and have effective means of disseminating the results of their researches and of stimulating their practical application.

11. Other facets of the same problem are the relations of Government research establishments with universities and with Government Departments, particularly those that do not have research establishments of their own.

12. Circumstances have changed radically since most of the Government's civil research organisations were first set up. Their foundations lie in the centuries-old scientific interests of the Admiralty, and in such institutions as the Royal Observatory, which, founded in 1675, was the first of all separate State-aided scientific institutions; the Geological Survey, founded in 1835; and the Department of the Government Chemist, founded in 1842. The National Physical Laboratory was established in 1900, under the control of the Royal Society, in response to the need to encourage physical and engineering research and, in particular, research into standards of measurement. Not until 1909 did the Government begin to assume a more comprehensive responsibility for promoting scientific activities. It was then that the Development Commission was founded to advise on scientific aid to agriculture, rural industries and fisheries. Four years later, in 1913—the Government was by then spending about £600,000 a year on the promotion of civil science—a Medical Research Committee was established. The Department of Scientific and Industrial Research was set up in 1916, with a general responsibility for initiating proposals relating to the advance of trade and industry by means of scientific research. The transformation of the old Medical Research Committee into the Medical Research Council as we know it to-day occurred in 1920. That step, more than any other, established the general model of the Research Council. In 1931 the Agricultural Research Council was set up, and in 1949 the Nature Conservancy. This, in brief, is the history of the main Government scientific institutions in the civil field. Their basic pattern was set thirty or forty years ago, to

fit contemporary needs as visualized at the time both by scientists and administrators.

13. The volume of research undertaken at the universities and in the larger industrial firms has grown considerably during this period, and many more Government Departments than in earlier days are directly concerned with massive programmes of capital and other development. To establish effective working relationships between all these bodies is not easy. But it is essential to do so if Government civil research is to be part, as it should be, of the main stream of our national life. We devote a good part of our report to a review of management techniques which might help to ensure this.

14. These then are the main issues on which our report focuses attention. Throughout our enquiries we have borne in mind that the work with which we are dealing is far from homogeneous. In each organisation it ranges from pure basic research through what we have called "objective basic" to applied research and development, and methods of control will vary according to the type of work. For example, time is not a significant factor in pure basic research, where the pace and intensity of the work must depend very largely upon the judgment and interests of the scientists concerned. In objective basic research, where the knowledge sought may be needed within a limited period in order to maintain the momentum of applied research projects, speed may be all-important. In applied research and development its importance is usually considerable, and it becomes vital in defence projects or in civil industry operating in highly competitive markets.

METHODS OF WORK

15. Most of the factual information contained in our report was obtained by means of questionnaires sent to the Research Councils, to the Atomic Energy Authority, and to those Government Departments which undertake substantial amounts of research and development. We also obtained a great deal of additional information, as well as valuable advice and opinions, from the many witnesses from both inside and outside Government, who have appeared before us in the course of some sixty meetings we have held over the past three years. These meetings have been kept informal, and we are grateful to our witnesses, some of whom we saw more than once, for the freedom with which they expressed their views. But the responsibility for our recommendations is of course ours alone.

16. A list of the organisations covered by the questionnaire and of the witnesses we have seen is given in Appendix I. The size of the net whereby we collected information was also effectively increased by the fact that individual members of the Committee at their discretion consulted many others with experience of the problems with which we have been dealing.

DEFINITIONS

17. We have taken "research and development" to mean, in general terms, all those activities which are directed towards the acquisition of

scientific facts and techniques, or towards their application, to the design of new or improved materials, or equipment, or to the devising of new processes, often involving, in the later stages, the construction of prototype equipment or pilot plant.

18. We have found it helpful to differentiate between five categories of activity normally included under the portmanteau term, research and development. These are pure basic research, objective basic research, applied (project) research, applied (operational) research, and development. Our definitions of these terms are set out in the following paragraphs. We would, however, emphasise two points. First, there is and can be no clear-cut line of demarcation between one form of research and another; basic research and development are, so to speak, bands at opposite ends of a continuous spectrum. Second, most organisations engaged in research will be concerned to some extent with the whole range of research and development.

(i) *Pure Basic Research.*

Pure basic rsearch is research carried out solely in order to increase scientific knowledge: that is, knowledge of the nature of the material world. Such research is commonly called either "fundamental" or "pure" or "basic". These words, particularly "fundamental", are often connected with the idea of work of high intellectual quality. A fair amount of "pure" scientific research may, however, be of a routine or of a preliminary nature. For example: (i) "filling in", where a main break-through has already been made; (ii) exploratory work in fields where a good deal of semi-empirical experimentation is needed before the real problems can be identified; (iii) descriptive observational work, notably in biology and geology. A line of "pure basic" research is selected by the individual worker to satisfy his own tastes and intellectual curiosity.

Examples of pure basic research are:

A study of the properties of high energy cosmic ray particles. The correlation of the chemical and structural changes that take place in muscle during its contraction and relaxation.

(ii) *Objective Basic Research.*

Between "pure" and "applied" research there lies an intermediate category of scientific work to which we have given the name "objective basic". This denotes basic research in fields of recognised potential technological importance. It is well known that the pursuit of defined technological objectives, for example the development of a supersonic aircraft, sometimes exposes an area in which existing scientific knowledge is seriously insufficient. It then becomes necessary to try to organise an increase in this knowledge before a further technological advance can be made. Research of this type may be as intellectually exacting as what we have called "pure basic" research. The difference between "pure basic" and "objective basic" research derives mainly from the fact that the latter is stimulated primarily by technological needs. It therefore calls for a planned approach even when the satisfaction of these needs is remote. This characteristic of "relevance"

to a definable technological objective is a practical criterion which differentiates " objective " basic research from " pure " basic research.

Examples of objective basic research are :

The study of the fundamentals of plasma physics, which may provide data likely to be of value to work on thermonuclear fusion directed to the harnessing of new sources of energy. A study of the growth of virus in living cells, which may provide information of value in combating virus infections of man.

(iii) & (iv) *Applied (Project or Operational) Research*

As indicated above, applied research has as its object the attaining of a practical goal, which can be fairly precisely defined, such as a new process or piece of equipment. We believe that this type of work is best described as *project research* to distinguish it from applied research directed to improving the use of an existing process or piece of equipment. The latter may be called *operational research.*

Examples of applied research are:

Project. To provide design data for a nuclear-powered submarine. To determine the cause of the specific failure of a particular crop and to derive a remedy to prevent its recurrence.

Operational. To improve the working performance of an existing type of graphite-moderated carbon dioxide-cooled nuclear reactor. To provide the data for improving the design and layout of farm buildings by a study of their purpose and day-to-day use.

(v) *Development*

Development bridges the gap between research and production. It may be defined as the work necessary to take, for example, a new process or piece of equipment to the production stage. It will often include the erection and operation of pilot plants or the construction of prototypes.

Examples of development are:

The work required to determine the best production techniques for the manufacture of solid fuel elements for a nuclear reactor, research having determined the necessary composition of the fuel elements and the material for the containers. The work required to determine the appropriate process for manufacturing penicillin on a large scale, research having established its antibiotic properties, and small-scale trials its clinical usefulness.

CHAPTER II

THE GENERAL ORGANISATION OF GOVERNMENT SCIENCE

19. This Chapter, which is purely factual, is in two parts. The first (up to paragraph 71) describes the various organisations responsible for Government research and development. The second analyses the estimates of expenditure on research and development for 1960-61 ; it shows the money and scientific man-power allocated to each of the main organisations or groups of organisations and, in general terms, the proportions which are devoted to basic research, applied research, and development respectively. Some of this information has not been published before.

THE PRINCIPAL ORGANISATIONS

20 The organisations covered by our terms of reference can be grouped under three headings ; Government Departments ; the Research Councils (including the Department of Scientific and Industrial Research which, although a Government Department, is under the general control of a Research Council) ; and the Atomic Energy Authority. In each case, the work may be undertaken either by the Government organisation itself or by way of extra-mural contracts let to industry or to a university.

21. These organisations are responsible for a total of some 280 establishments and units. The complete list is given in Appendix II,* which indicates the general field of study of each establishment (where this is not clear from the title), and the number of qualified scientists and engineers employed.

GOVERNMENT DEPARTMENTS

DEFENCE RESEARCH AND DEVELOPMENT

22. The Ministry of Defence has the overriding responsibility for defence research and development, but each of the three Service Departments formulates its own operational requirements and is responsible for the carrying out of certain types of research and development. These responsibilities for research and development, and for supply and production, including those of the Ministry of Aviation, are broadly as follows:

Admiralty:	naval vessels and conventional weapons and equipment for the Navy ; electronic valve research for all three Services.
Air Ministry:	meteorology and aviation medicine (both with considerable application in the civil field).
War Office:	conventional weapons and equipment for the Army. and—for all three Services—ammunition, clothing, general stores and vehicles.

* For reasons of security this list does not give the number of staff in defence research and AEA establishments.

Ministry of Aviation:	on behalf of all three Services—aircraft and associated equipment, guided missiles and atomic weapons and a considerable proportion of the requirements for radar, radio and electronics.

In addition, each of these Departments undertakes operational research (the Ministry of Aviation in the civil field only) and is also responsible, within its own field, for stimulating and fostering research in areas of science and technology of potential importance for defence.

23. We describe these responsibilities for defence research and development in greater detail in Chapter VI.

24. In addition to putting work out under contract to industry, the Ministry of Aviation, the Admiralty and the War Office have under their direct control 44 research and development establishments and units, some of which are among the largest in the country (see Appendix II).

CIVIL RESEARCH AND DEVELOPMENT

25. In addition to his specific responsibilities to Parliament for the Research Councils and the Atomic Energy Authority (see paragraphs 29 and 55), the Minister for Science is also responsible for the formulation and execution of Government scientific policy on questions which relate to civil science as a whole. Responsibility for the scientific work of the separate Departments of State rests with the Ministers concerned.

26. The main fields in which Government Departments undertake to sponsor civil research and development are as follows :—

Admiralty:	astronomy and oceanography.
Ministry of Agriculture, Fisheries and Food:	agriculture, botany, fisheries, food science, veterinary science, sea defences.
Air Ministry:	meteorology and aviation medicine.
Ministry of Aviation:	civil transport aircraft, aids to navigation, air traffic control; space science.
British Museum:	the scientific examination and new methods of conservation of antiquities and works of art.
British Museum (Nat. History):	systematic zoology, botany, entomology and mineralogy.
Colonial Office: *	geology and related subjects, oceanography, general assistance to research and development in the dependent territories.
Ministry of Education:	educational buildings.
Forestry Commission:	forestry.
Ministry of Health:	public health.
Home Office:	forensic science, civil defence and fire services.

* These responsibilities now fall on the Department of Technical Co-operation which came into being on the 24th July, 1961.

National Gallery:	the scientific examination and new methods of conservation of paintings.
Post Office:	telecommunications, postal services.
Ministry of Power:	safety in mines, economic utilisation of fuel and power.
Royal Mint:	coinage materials.
Ministry of Transport:	shipping (radio-aids to navigation); roads (traffic and safety).
Scottish Departments:	agriculture, fisheries, astronomy, public health.

The research establishments, institutes and stations of these Departments are listed in Appendix II.

27. In addition to the above Departments the Development Commission, which is responsible for recommending expenditure from the Development Fund, supports research relating to marine and freshwater fisheries undertaken by independent institutes such as the universities and the Marine and Freshwater Biological Associations (see Appendix II). The Commission's Advisory Committee on Fisheries Research also advises those Government Departments concerned with fisheries research and co-ordinates the work of all Government and independent laboratories undertaking such research. Payments are also made from the Funds to the National Institute of Oceanography and in support of research on the use of seaweed.

THE RESEARCH COUNCILS

28. Under this heading we group the Agricultural Research Council, the Council for Scientific and Industrial Research, the Medical Research Council, and the Nature Conservancy.* The Council for Scientific and Industrial Research is the governing body of the Department of Scientific and Industrial Research, whose funds are made available, as for Government Departments generally, by way of a Parliamentary Vote. The Medical Research Council, the Agricultural Research Council and the Nature Conservancy, on the other hand, are supported by grants-in-aid provided by Parliament.

29. The four Research Councils are responsible to their respective Committees of the Privy Council of which the Minister for Science is the Chairman, the other members being those Ministers whose Departments have a special interest in the work of the particular Council. For example, the Minister of Health is a member of the Committee of Privy Council for Medical Research and the Minister of Agriculture is a member of the Committee of Privy Council for Agricultural Research and of the Committee of Privy Council for Nature Conservation.

THE AGRICULTURAL RESEARCH COUNCIL

30. The Agricultural Research Council (A.R.C.) consists of a Chairman and seventeen other members—nine independent scientists, four farmers, two official scientists and two other officials. The Secretary of the Council is responsible for the administration of all its activities, and is Accounting Officer under the terms of the Agricultural Research Act, 1956. The Council

* The recently established Overseas Research Council does not itself conduct research. Its functions are to advise on the formulation of policy relating to scientific research in or for overseas countries and to co-ordinate scientific advice and assistance given to them.

has two Standing Committees dealing with research affecting Plants and Soils, and Animals, respectively, six other main committees advising on certain broad aspects of its work, and some fourteen technical committees. It also participates in a number of joint committees with other organisations.

31. The A.R.C. maintains contact with the agricultural industry in England and Wales through the Ministry of Agriculture and the National Agricultural Advisory Service (N.A.A.S.).* North of the Border its link is with the Department of Agriculture for Scotland and the parallel advisory services based on the three Colleges of Agriculture, which are supported by grants from that Department. In addition, the A.R.C. is represented on the Joint Committees of the Agricultural Improvement Councils (A.I.C.) of the Ministry of Agriculture and the Department of Agriculture for Scotland.

32. Development work and the application of results of research are largely the responsibility of the Ministry of Agriculture and N.A.A.S. The Ministry is assisted in this work by the Agricultural Improvement Council for England and Wales which, in addition to its advisory role in relation to agricultural and horticultural problems in general, is charged to keep under review "the progress of research with a view to ensuring that promising results are applied as rapidly as possible to the problems of agriculture and horticulture and that these and any other new technical methods are incorporated into ordinary commercial practice". This Council is also responsible for the general oversight of the work of the N.A.A.S. experimental husbandry farms and horticultural stations. Corresponding arrangements exist in Scotland.

33. The A.R.C. is responsible generally for the organisation and development of agricultural research and, in addition, has recently taken over the responsibility for research into the processing and storage of food (other than fish) which was previously carried out by D.S.I.R. The Council has under its direct control seven research institutes, three other small research establishments, as well as fourteen units (thirteen of which are attached to University departments), and a statistical group. It is also responsible for financing the independent but State-aided agricultural research institutes of which there are fourteen in England and Wales; and it collaborates with the Department of Agriculture for Scotland, through which eight similar State-aided institutes are financed in Scotland. The A.R.C. is thus in a position to co-ordinate the work of all the forty-seven agricultural research stations, institutes and units in Great Britain (see Appendix II). The Council also makes grants to universities and other bodies for special investigations, and awards research fellowships and post-graduate studentships in agriculture and veterinary science.

34. The A.R.C. co-ordinates the work of its establishments and units and of the various State-aided research institutes with a view to matching their combined programmes of research to user needs. The Council is assisted in this task by the Joint A.I.C./A.R.C. Committee which examines the research requirements of each of the main agricultural commodities

* In addition to its advisory role, the N.A.A.S., which is administered by the Ministry of Agriculture, carries out applied research and development in its 18 experimental husbandry farms and horticultural stations.

produced in this country and which provides an assessment of research priorities. The Joint Committee has completed its work for the moment.

35. The detailed programmes of work for each establishment or unit are determined by the senior staff directly engaged on research, and are tailored to the total resources (in terms of money and manpower) allotted to them by the Council through the machinery of annual estimates. These programmes are reviewed every five or six years by independent *ad hoc* Visiting Groups appointed by the Council, and made up of experts in the work covered by the particular establishment under review. These Groups, which have access to the commodity surveys carried out by the Joint Committee referred to in the preceding paragraph, assess the work of members of the research staffs as well as the programme of the establishment as a whole. Their findings assist the Council in deciding the adequacy of the research effort, both basic and applied, in relation to its importance to agriculture.

The Council of Scientific and Industrial Research

36. The Council of Scientific and Industrial Research consists of a Chairman and eleven members drawn mainly from industry and the universities. The Secretary of the Council is also the Permanent Secretary of the Department of Scientific and Industrial Research (D.S.I.R.). At present the Council has eight main advisory committees (apart from those concerned with the work of individual research stations) dealing respectively with industrial grants, research grants, post-graduate training awards, human sciences, economics, development, the dissemination of information, and the Council's stations as a whole. At the Headquarters of the Department there are three groups dealing respectively with (i) the Department's stations and relations with industry; (ii) grants, information and overseas liaison; and (iii) finance and "Establishment and Organisation" matters generally.

37. The Council determines the broad pattern of the work of the Department and of its fifteen research stations (see Appendix II) and decides priorities by reference to the current and future research requirements of a wide range of industrial and social activities. The detailed programme of individual stations, which are all engaged on "investigations relating to the advancement of industry and trade", are largely determined either by the Directors and their senior staff assisted by an Advisory Board or by a Steering Committee.

38. D.S.I.R. encourages and supports scientific research in the universities and colleges of technology by means of grants for "work of special timeliness and promise", and for individual post-graduate workers in science and technology.

39. The Department is also responsible for stimulating the application in industry of the results of scientific and technological research. To this end it supplements the payments made by industry to the various industrial research associations. The Department keeps in touch with industry and the industrial research associations in a number of ways. For example, industrialists serve on the Council, its Boards and Committees, and D.S.I.R. representatives also serve on the Councils and Committees of the industrial

research associations. Each research station and research association has direct contact with those industries with which its work is mainly connected and the results of research are disseminated by means of special reports, practical demonstrations and liaison visits. These also provide a channel for a reverse flow from industry of suggestions for modifications and innovations in the Department's research programmes.

40. The flow of information to and from the research laboratories is supplemented by the work of the Headquarters Information Division, the D.S.I.R. branch offices in Edinburgh and Cardiff, and other regional technical information centres which are grant-aided by D.S.I.R. The activities of the Information Division cover the use of publications, the press, broadcasting, films, exhibitions, and liaison overseas through the British Commonwealth Scientific Attachés in London and the scientific attachés appointed by D.S.I.R. in Bonn, Moscow, New Delhi, Paris, Stockholm, Tokyo and Washington. Another major responsibility of D.S.I.R. in providing technical help to industry is the organisation of the National Lending Library for Science and Technology.

41. We leave until Chapters IV and V the description of the arrangements by which D.S.I.R. formulates and controls the programmes of its stations and keeps in touch with the industries and Departments likely to benefit from its work.

The Medical Research Council

42. The Medical Research Council (M.R.C.) has twelve members: nine scientific members (drawn almost solely from the Universities) representing different branches of medicine and fundamental science; and three lay members, one of whom must be a member of the House of Lords and one a member of the House of Commons. It is customary for the House of Lords member to be elected Chairman. The Secretary of the Council is responsible for the administration of all its activities. The Council has two main Boards, the Clinical Research Board and the Tropical Medicine Research Board. It is assisted by sixty-one advisory committees and by five committees appointed jointly with other bodies to advise on matters of common interest.

43. The Chief Medical Officers of the Ministry of Health and the Department of Health for Scotland, the Biological Secretary of the Royal Society, the Secretaries of the D.S.I.R. and the A.R.C., and the Chairman of the University Grants Committee have been appointed Assessors by the Council. The first three regularly attend Council meetings and take part in its discussions. The representatives of the Health Departments also attend the meetings of the Clinical Research Board, while the Commonwealth Relations Office and the Colonial Office are represented at the meetings of the Tropical Medicine Research Board.

44. The M.R.C. promotes research likely to be of value in the field of curative and preventative medicine. In the United Kingdom it has one large establishment (the National Institute for Medical Research) and 71 research units, most of which are attached to university departments or hospitals. The Council also undertakes work overseas and, with support from Colonial Development and Welfare funds, maintain laboratories in the Gambia and

research units in Uganda and Jamaica (see Appendix II). The Council also employs a number of individual research workers (" external scientific staff "), attached mainly to University departments, who undertake research in particular subjects for which special opportunities are available. In addition, the Council provides major support through block grants for five institutions, the largest of these being the Institute of Cancer Research.

45. Responsibility for " development " work lies with the Ministry of Health and the Department of Health for Scotland and, in the case of Service personnel, with the Service Departments, but commercial firms and the medical profession are also much concerned in these activities, on which the M.R.C. may be called upon to advise.

46. The M.R.C. makes temporary grants to workers in universities and elsewhere in support of specific research projects initiated by the individuals concerned. Under a newly constituted scheme of " Research Groups ", the Council provides support on a longer term basis with a view to accelerating, where it would be in the national interest to do so, the progress of research in university departments, on the understanding that if the university wishes the work to continue it will incorporate the group in its own structure after an agreed interval of not less than five but rarely more than ten years. The Council also awards fellowships and scholarships for training in research methods.

47. The M.R.C.'s recognition of the role of the universities in pure research is shown by the importance attached to locating research units, wherever possible, in universities, medical schools or teaching hospitals. On the other hand, the M.R.C. believes that some fundamental problems can best be tackled on a multi-discipline basis and that the necessary co-operative effort can be most effectively organised in a single institute, rather than by attempting to co-ordinate and direct the work of a number of separate centres. In addition to the National Institute for Medical Research, which is primarily concerned with research in non-clinical subjects, the Council has recently decided to set up a Clinical Research Centre with a view to bringing groups of clinical and related subjects together.

48. The general principle followed by the M.R.C. is to leave the selection of projects and their detailed control to senior research staff (i.e. the Director and heads of Divisions at the National Institute for Medical Research and the Directors of the various units) once the field to be covered and the level of effort required has been agreed by the Council. The Council finds it neither practicable nor desirable to fix a time-scale for the completion of a particular investigation. A general oversight of existing work is maintained by the following arrangements.

49. Directors of research units, and members of the Council's external staff working independently, submit to Council detailed progress reports of their work at intervals of three or so years. Directors are also invited periodically to attend meetings of the Council or its Boards to report on the work of their Units and to discuss future plans. In addition, the Secretary regularly visits the Council's research units, while the Council not infrequently appoints *ad hoc* committees, mainly of its own members, to visit particular establishments and to report back. Because of its special status, the National

Institute for Medical Research is visited by the whole Council once a year, and an annual report is received from the Director. The work of all units is briefly reviewed each year at a special meeting of the Council, when the estimates are being prepared.

50. From time to time, the Council itself plays a more positive role in determining the content of programmes. Each year it considers a list of special topics, e.g. psychiatry, nutrition, tuberculosis, to be reviewed in the following year at successive monthly meetings. In these reviews, which usually cover the work of several units, the emphasis is on a survey of likely developments. The aim is to consider sources of new knowledge and opportunities for making useful advances. Alternatively, in a field showing diminishing returns, because of the lack of new ideas or of available techniques, the Council has to judge whether there is sufficient likelihood of discovering some fresh idea or new technique to justify further expenditure. In addition, through the Council's structure of scientific committees, the fields covered are kept under running review. For example, the Clinical Research Board undertakes a series of monthly reviews on the lines of those undertaken by the Council, and the same practice is followed by the Tropical Medicine Research Board at its quarterly meetings.

The Nature Conservancy

51. The Nature Conservancy consists of a Chairman and seventeen members, with a Director-General responsible for the administration of its various activities. It has delegated certain responsibilities to three main territorial committees concerned respectively with England, Wales and Scotland. It is advised on scientific policy by its Scientific Policy Committee. There are other central and local committees concerned with finance, grants, photography and other matters.

52. The Conservancy provides scientific advice on the conservation and control of the natural flora and fauna of Great Britain; establishes, maintains and manages reserves, including the maintenance of physical features of scientific interest; and organises and develops such research and scientific services as may be necessary. The Council makes grants in support of research, in particular to university scientists, and awards a number of post-graduate studentships.

53. The Nature Conservancy employs scientific staff on conservation work and research. The research, which is mainly basic in character, is undertaken at a number of research and field stations. Scientists engaged on research are based also on the headquarters in London, Edinburgh and Bangor and at regional offices (see Appendix II).

54. Because of its responsibilities for advising on the natural flora and fauna of Great Britain and the establishment of nature reserves, the Nature Conservancy has to maintain a close liaison with a wide range of organisations, including not only Departments of central government, local government organisations and the universities, but also numerous bodies representing, for example, landowners, naturalists, sportsmen and those concerned with recreation and amenity.

THE ATOMIC ENERGY AUTHORITY

55. The Atomic Energy Authority (A.E.A.), like other statutory public corporations, is free from day-to-day Government control (subject to the power given to the Minister for Science to issue directions to the Authority in matters of overriding national importance), but differs from them in that its expenditure is met out of funds voted by Parliament on the basis of annual estimates.

56. The Authority's powers in the field of atomic energy are comprehensive, and cover the production, use, and all forms of research into, atomic energy and radioactive substances and the disposal of radioactive waste. Its major tasks are to produce fissile material for the defence programme ; to conduct basic and applied research and development work in its own establishments for the nuclear power programme ; and to manufacture fuel elements for its own nuclear reactors and for those of the electricity generating authorities. On the defence side the A.E.A. develops and produces atomic weapons or components by agreement with and on behalf of the Ministry of Aviation.

57. The A.E.A. consists of a full-time Chairman and Deputy Chairman and ten other members (four of whom are full-time). In addition to the Head Office in London there are five groups, each with a considerable measure of autonomy; the Research Group, the Reactor Group, the Weapons Group, the Production Group, and the Engineering Group.

58. The Authority concerns itself mainly with policy, including all major proposals for expenditure. The full-time members, together with the Directors and Managing Directors of the Five Groups, form a management committee known as the Atomic Energy Executive which, subject to policy laid down by the Authority, carries out the general management of the Authority's affairs and co-ordinates the activities of the five groups, with the Chairman effectively in the position of Executive Chairman.

59. The London Headquarters Offices are concerned with finance and accounting, general administration, commercial negotiations and contracts, patents, security and non-technical aspects of health and safety policies, as well as with the procurement of uranium and other special materials and with arranging collaboration with industry at home and with countries overseas.

60. The Heads of Groups are responsible to the Authority, through the Executive, for the conduct, efficiency and well-being of their establishments. Each Group has a Management Board consisting of the Head of the Group as chairman, and the principal officers of the Group as members, together with a representative from each of the other Groups and from the London Office.

61. The Deputy Chairman is responsible for scientific and technical co-ordination throughout the Authority; the Member for Weapons Research and Development for the weapons research and development programme; and the Member for Reactors for the design and development of reactors, in addition to other responsibilities described in paragraph 64.

62. The Deputy Chairman exercises his responsibilities through the Research Policy Committee, of which he is Chairman. The remaining members of the Committee are the Director of the Research Group (who is also the Director of the Atomic Energy Research Establishment, Harwell), the Directors of the Atomic Energy Establishment (Winfrith), the Dounreay Experimental Research Establishment, the Atomic Weapons Research Establishment, the Deputy Managing Director, Development (Reactor Group) and a representative of the Production Group. The Committee's task is to inspect the progress of research work in the various establishments and laboratories (listed in Appendix II) and to advise the Authority on the total research effort in manpower and money, its distribution between subjects and between establishments, and the priority to be assigned to particular items.

63. The Research Group carries out basic and applied research (other than research on atomic weapons). Some basic and much applied research is also carried out by the other Groups of the Authority. The Management Board of the Research Group formally handles all major policy questions, supervises the expenditure of the Group's budget and is responsible for the control of research and development throughout the Group.

64. The Reactor Group is responsible for the design and development of reactors and for relations in this field with industry at home and abroad. The Group includes the Dounreay Experimental Research Establishment and the Atomic Energy Establishment, Winfrith, and is also responsible for the work of the laboratories at Risley, Springfields, Culcheth and Windscale.

65. The Weapons Group carries out some civil research in addition to its main work on weapons, and the Production Group some research in aid of factory processes. The Engineering Group's responsibilities include the design of plant and buildings and the design and inspection of fuel elements for production purposes.

66. The Authority has many contacts with industry, in particular with the industrial consortia set up to undertake the construction of nuclear power stations. Considerable numbers of professional and technical staff from industry work alongside the Authority's own staff on particular projects. Close contacts with the electricity generating authorities are also maintained, and the Authority collaborates with a number of Government Departments and Research Councils on research into health and safety problems in the atomic energy field and on the industrial use of radio-isotopes. Through contracts for extra-mural work, links are maintained with university scientists who also make frequent use of the large experimental installations at Harwell.

67. Further reference is made in Chapters IV and V to the way in which the A.E.A. determines and controls the research and development programmes of its establishments.

The National Institute for Research in Nuclear Science

68. The National Institute for Research in Nuclear Science (N.I.R.N.S.) was set up to provide for university scientists large scale facilities which were

beyond the reach of individual universities. It is financed through the vote of the A.E.A. but is not controlled by the Authority. The Institute's Rutherford Laboratory is situated just outside Harwell.

GENERAL ADVISORY COMMITTEES

69. There are two main bodies which advise the Government on general policy: on the civil side the Advisory Council on Scientific Policy (A.C.S.P.), and for defence, the Defence Research Policy Committee (D.R.P.C.). The A.C.S.P. advises the Minister for Science " in the exercise of his responsibilities for the formulation and execution of Government scientific policy ". It has no executive responsibilities. The Council includes scientists drawn from the universities, the colleges of advanced technology, industry and Government service, including the Secretaries of the Research Councils and the Director-General of the Nature Conservancy.

70. The D.R.P.C. advises the Minister of Defence and the Chiefs of Staff " on all scientific and technical matters which may affect the formulation and direction of defence policy ". It is also charged " to keep under review the defence research and development programme so as to ensure that it is appropriate to current defence policy having regard to available resources ". It is thus responsible for the oversight of the defence research and development programme as a whole and for the allocation of inter-Service priorities. The Committee is under the chairmanship of the Chief Scientific Adviser to the Minister of Defence, and includes representatives of the Chiefs of Staff and the Scientific Advisers and Controllers responsible for research and development in the Service Departments and in the Ministry of Aviation. Thus all its members are officials with executive responsibilities for various aspects of research and development.

71. There are also a number of other bodies concerned in an advisory or co-ordinating capacity with particular aspects of policy—or with policy in particular areas of research—for example, the Overseas Research Council (see footnote to paragraph 28) and the Steering Group on Space Research, set up to assist the Minister for Science with his task of co-ordinating our space research effort.

RESEARCH AND DEVELOPMENT IN TERMS OF MONEY AND MANPOWER

72. Table I shows the total expenditure (capital as well as current) on research and development by Government Departments and the Research Councils. University research financed by the Treasury grant to the University Grants Committee is not included, nor for security reasons is expenditure by the Atomic Energy Authority.

TABLE I

Estimated expenditure (1960/61)* on research and development

		£m
Government Departments		
(a) Defence Departments(1) ...		242
(b) Civil Departments ...		12
Research Councils(2)	£m	
A.R.C. ...	6·4	
D.S.I.R. ...	15·1	
M.R.C. ...	4·3	
Nature Conservancy ...	0·5	26
National Institute for Research in Nuclear Science (N.I.R.N.S.)(3)	...	6
		£m 286

Notes (1) Including extra-mural work of about £175m. in industry and of about £0·5m. in the universities and other non-profit-making organisations.
(2) Including grants to post-graduate workers, for special researches, and to industrial research organisations.
(3) Including non-recurrent expenditure of £4,500,000.

73. Table II shows the scientific manpower employed in establishments under the aegis of Government Departments and the Research Councils (but excluding the A.E.A.). Column A includes, broadly speaking, all those who have studied science up to at least G.C.E. Advanced level. Column B is restricted, in general, to those with First and Second Class Honours degrees or equivalent qualifications.

TABLE II

Research and development effort in terms of manpower (as at 1.4.59)

	Col. A(1)		*Col. B(2)*	
Government Departments				
(a) Defence ...		5,270		1,900
(b) Civil (approx.) ...		2,200		900
Research Councils				
A.R.C. ...	1,540	say 4,400	815	say 2,300
D.S.I.R. ...	1,835		745	
M.R.C. ...	850		695	
Nature Conservancy(3) ...	70		35	
N.I.R.N.S.(4) ...	125		55	

Notes (1) Staff in the Scientific Officer Class and the Experimental Officer Class of the Scientific Civil Service (whose duties and qualifications are set out in Appendix VI) and their equivalents in the A.R.C. and M.R.C. Also included are staff with degrees in engineering and those who have satisfied the examination requirements for corporate membership of certain professional bodies such as the Institution of Electrical Engineers; and, for the M.R.C., medically qualified research workers.
(2) Manpower as for Column A, but excluding the Experimental Officer Class and its equivalents in the A.R.C. and M.R.C.
(3) Including conservation staff.
(4) Staff at 1.1.61 (excluding engineers engaged on design, construction and maintenance.)

74. Each qualified research worker in the physical sciences normally needs more supporting staff than his opposite number in the biological sciences. Thus, whereas in Column A the D.S.I.R. total is more than twice as large as that of the M.R.C., in Column B the D.S.I.R. figure is only slightly larger than the M.R.C. figure. Similarly, defence research and development accounts for nearly half the total scientific and technical man-

* Civil estimates and estimates for Revenue Departments (1960–61); Memorandum by the Financial Secretary to the Treasury, H.M.S.O. 16th February, 1960 and Civil Estimates (1960–61), Class IX, 7, Atomic Energy. The estimates for the Research Councils were taken from the Annual Report of the Advisory Council on Scientific Policy 1959–60 (Appendix E).

power as defined in Note (1) but only for about two-fifths of those with the higher qualifications.

ALLOCATION OF EFFORT BETWEEN BASIC RESEARCH, APPLIED RESEARCH AND DEVELOPMENT

75. We asked the Research Councils, the A.E.A. and the main Government Departments engaged in research and development, to estimate the proportion of their total effort—in terms of manpower and money—devoted to basic research, applied research and development respectively (using the definitions given in Chapter I as a guide). The replies are not strictly comparable, but the figures in Tables III and IV are, we think, reasonably reliable as broad approximations.

76. Table III shows the allocation of current expenditure between basic research, applied research and development. In defence, expenditure on development predominates, while expenditure on basic research accounts for only a small proportion. Conversely, the Research Councils devote a high proportion to basic research and spend relatively little on development.

TABLE III

Allocation of expenditure between basic research, applied research and development (1959/60)

	Basic %	*Applied* %	*Development* %
Government Departments			
(*a*) Defence	1	19	80
(*b*) Civil (very approx.)	5	45	50
Research Councils(1)	40	55	5
Atomic Energy Authority(2) (civil only)	20	50	30

Notes (1) Excluding N.I.R.N.S., and D.S.I.R. grants for university work and to the industrial research associations. Including N.I.R.N.S. the percentages are basic 55%, applied 41% and development 4%.
(2) Excluding N.I.R.N.S.

77. In terms of scientific and technical manpower the proportion of effort devoted to basic research in Government establishments is relatively higher, and the proportion on development is correspondingly lower, than the proportions in terms of finance, as shown in Table IV. This is due to the large amount of development work carried out in industry for the Government Departments concerned, particularly the Defence Departments. On the other hand, these differences are far less marked in the A.E.A., which carries out a relatively large amount of development work in its own establishments.

TABLE IV

Analysis of manpower(1) allocated to basic research, applied research and development (1959/60)

	Basic %	*Applied* %	*Development* %
Government Departments			
(*a*) Defence	3	48·5	48·5
(*b*) Civil (very approx.)	10	60	30
Research Councils(2)	40	55	5
Atomic Energy Authority(3) (civil only)	15	50	35

Notes (1) As defined in Note (1) to Table II.
(2) Including N.I.R.N.S. these percentages would be basic 42%, applied 53% and development 5%.
(3) Excluding N.I.R.N.S.

Civil Research and Development

CHAPTER III

BASIC RESEARCH

78. The main questions discussed in this Chapter are the extent to which Government research establishments should themselves engage in basic research, and how management can best stimulate, guide and help the research worker. Because work of this kind predominates in the activities of the M.R.C. and the A.R.C., the observations we make in this Chapter are focused on these two organisations. We should make it clear, however, that all Government research establishments undertake a certain amount of basic work. The Atomic Energy Authority's direct effort* in basic research, carried out mainly at the Atomic Energy Research Establishment at Harwell and at the Atomic Weapons Research Establishment at Aldermaston, is considerable. Similarly, a number of research establishments of D.S.I.R. and of Government Departments devote a comparatively high proportion of their total resources to basic scientific work. In the case of D.S.I.R. this is true of the National Physical Laboratory and of the Geological Survey; in the case of defence establishments, of the Microbiological Research Establishment at Porton, the Royal Aircraft Establishment at Farnborough, the Royal Radar Establishment at Malvern and the Admiralty Research Laboratory at Teddington; and, to take one example from civil Departments, of the British Museum (Natural History).

79. The total resources which the Government devotes to basic research cannot be calculated exactly. But if we relate the "basic research" percentages in Table III of Chapter II to the expenditure figures in Table I of the same Chapter we obtain some indication of the amount organisations wholly financed by Government spend on such work (excluding expenditure by the Atomic Energy Authority). This is shown in Table V.

TABLE V

	£
Government Departments	
(a) Defence(¹)	2,400,000
(b) Civil (very approx.)	600,000
Research Councils(²)	7,500,000
National Institute for Research in Nuclear Science(³)	6,250,000
	£16,750,000

Notes (¹) Including extra-mural research contracts.
(²) Excluding grants by D.S.I.R. for university work and to the industrial research associations.
(³) Including non-recurrent expenditure of £4,500,000.

80. As noted in Chapter I, we distinguish "pure basic research", by which we mean basic research carried out for the sole purpose of increasing scientific knowledge (and with no immediately recognisable field of appli-

* That is, excluding the work of the National Institute for Research in Nuclear Science.

cation), from "objective basic research", by which we mean basic research stimulated primarily by some practical need in a field of potential application. While the greater part of Government basic research can probably be regarded as "objective basic" in character, we have found it useful to distinguish between the two categories in considering how far Government laboratories should themselves engage in basic research.

Extent to which Government Establishments should engage in Basic Research

81. In our view, pure basic research is best carried out in the environment of a university rather than in that of a Government research establishment. It is a characteristic of universities that they provide their members with the necessary freedom to pursue any line of enquiry they wish to follow and, broadly speaking, at whatever pace their inclinations dictate. In the choice of work a research worker in a university need take no account of the needs of industry or of national priorities. Normally he is free from the immediate pressures exerted by those concerned with the applications of the results of his work. Colleagues who work in his own and related disciplines provide a vital stimulus and can act as touchstones for new ideas. We do not, of course, suggest that comparable conditions cannot be established outside the academic world, but they are far less likely to be realised either in Government or industrial research establishments, the justification for whose existence is that they bring science to bear on the solution of relatively immediate practical problems.

82. While pure basic research should seldom be their direct concern, Government scientific organisations should nevertheless encourage and support such research in fields which appear to need assistance. In particular, we believe that Government research organisations have a major part to play in providing costly research equipment which is beyond the resources that could reasonably be made available to a single university or group of universities. This kind of help is illustrated by the arrangements which have been made through the A.E.A., in their own establishments and by way of the National Institute for Research in Nuclear Science.

83. Unlike what we call pure basic research, objective basic research, undertaken in order to try to fill a known gap in a field of potential practical importance, is very much the direct concern of Government research organisations. It is, of course, also the concern of industrial laboratories and, to a certain extent, of the universities. Its great importance to Government science does not, however, mean that Government organisations should arrange for their own establishments to undertake, either wholly or partly, all such research.

84. If objective basic research is to be carried out with any real prospect of success it cannot be treated as a simple routine activity. Generally speaking, it is as intellectually demanding as is pure basic research. It requires for its success the highest intellectual qualities; imagination coupled with doubt, flexibility with persistence, and precision with daring. Its pursuit within any establishment is,

therefore, justified only if the staff includes first-class research workers who are in close and constant touch with other scientists working in related fields of pure basic research. If this condition is not satisfied, the quality of the objective basic research carried out in Government establishments, whose main concern is bound to be applied research and development, is likely to be poor. This risk becomes all the greater the more work is carried out either by small groups or by individuals who are isolated from their colleagues on the applied side, and from work corresponding to their own in the universities.

85. Subject to the general proviso referred to in the preceding paragraph, the following circumstances, in our view, justify the undertaking of objective basic research in Government research organisations:—

(*a*) Where the Government has a prime responsibility, as in the setting of physical and pharmacological standards or, in the field of astronomy, for the compilation of the Nautical Almanac.

(*b*) Where the national interest requires a major and early advance into a new field, or a greater effort in an existing field, especially where substantial expenditure is involved and where the results are likely to be of value to many users.

(*c*) Where the basic studies involve the use of expensive facilities which are already available (or largely available) at Government establishments.

(*d*) Where a new organisation or combination of scientific resources is required which is beyond the capacity of any one university or group of universities as, for example, in certain fields of ecology.

(*e*) Where there are special advantages in linking the basic work with related applied research projects. It may be, for example, that equipment (including, in agriculture, experimental stock and field plots) and supporting staff could be shared. Under this head, there may also be cases in which the bringing together of basic and applied research in a Government establishment may be the best, or only, practical way of avoiding the dangers of isolated, watertight compartments of highly specialised work; or of securing the obvious advantages, such as mutual intellectual stimulus, of combining those engaged in basic research and those engaged in applied research into a team. In such cases, those carrying out basic research can also act as a link with those working in similar and related fields in the universities; we shall be repeatedly stressing in our report the importance we attach to such links.

(*f*) Where security considerations preclude university staff from co-operating with men engaged in particular lines of defence research.

86. We do not, of course, suggest that this is a comprehensive list of the circumstances which would justify Government establishments undertaking a research project of an "objective basic" character. For example, the best qualified staff for a particular job may be available only in a Government establishment; or only a Government establishment may have ready to hand the resources needed if the results are to be assured within a

limited period. Again, there may be occasions where problems can best be tackled on a multi-discipline basis, and where the necessary co-operative effort can most effectively be organised in a large institute which no single university could finance.

87. Correspondingly, we believe that Government laboratories derive much of value through arranging for the carrying out of objective basic research in a university or some other appropriate laboratory. Extra-mural contracts of this kind are neither a "second-best" nor a sign of inadequacy on the part of the Government research organisations concerned. The links they help forge with universities are valuable to Government laboratories, at the same time as the university scientist benefits by being made aware of the potential practical value of particular advances in knowledge. The ideal situation is perhaps achieved where a Government organisation can justify the undertaking of some objective basic research within its own establishments and at the same time sponsor related extra-mural work at a university.

88. In the course of our enquiries we often had impressed on us that many, if not most, young research workers with high qualifications want to do basic research, and that the opportunity to undertake such work is, therefore, an important factor in the recruitment of new graduates (or of those who have recently acquired higher degrees) to research establishments whose primary interests are clearly in applied research and development. However much they may be attracted by the problems arising in a field of applied research, many research workers feel that their reputation as scientists requires that they spend at least part of their working lives in contributing to the advancement of fundamental knowledge. For this reason, so it has been suggested to us, Government research establishments should ensure that their programmes include sufficient basic research to attract and retain a reasonable share of outstanding scientists. It is also held that the stimulus which the outstanding man can provide throughout an establishment is at least as important as the direct contribution made by his personal work.

89. We have some sympathy with this view. But we do not agree that Government research establishments should undertake basic research just because it might help recruitment and provide an intellectual stimulus for the staff. Indeed, if the promise of such work ever became an overt inducement to recruitment, we suspect that it would lead only too often to so-called fundamental work being pursued in a back-water remote from the main stream of scientific activity and with little concern for practical applications, and that in the long run it would neither help recruitment nor provide an effective intellectual stimulus. Government laboratories with a good reputation should hardly have to go out of their way to advertise the fact that, in the discharge of their responsibilities, they provide ample opportunities for outstanding men to undertake basic research.

90. We therefore recommend that Government research organisations should ask the Directors of their establishments to be guided largely by the considerations set out in paragraphs 84 to 86 in deciding whether to

undertake a new project in basic research, and also to consider whether certain of their established lines of basic research, if they are to continue, might not be transferred to a university.

THE ROLE OF MANAGEMENT

91. Our view, then, is that so far as basic research is concerned, Government establishments should concentrate on objective basic as opposed to pure basic research, i.e. on work which falls within the general objectives of the establishment concerned.

92. As we have said, work of this kind can be just as exciting, rewarding, and intellectually exacting as pure basic research. For example, there is the work of the National Physical Laboratory on the properties of existing materials and the synthesis of new materials under high pressures; that of the Royal Radar Establishment on the effect of controlled impurities on semiconductors which has led to the development of sensitive infra-red detectors with extremely rapid response time; the discovery, at the National Institute of Medical Research, of a natural substance (" interferon ") showing antiviral activity against a wide range of viruses; and the immunological work on anthrax which has been carried out at the Microbiological Research Establishment. We hope that all those who are in responsible positions in the world of science, both outside and inside government, will help to bring home both to young science students and to the public generally the worthwhileness and importance of objective basic research, of which we have mentioned but a few examples, carried out in Government research organisations.

93. For a laboratory to achieve a reputation for its basic research the first essential is to recruit and maintain a flow of first-class research workers, and to encourage them to develop their interests within the general field with which the establishment is concerned. The main problem facing management is that of reconciling the individual worker's desire for freedom from control, with tactful guidance designed to maintain the " objective " character of the work.

SELECTION OF PROJECTS

94. Within an establishment's allotted field, and provided the resources made available are commensurate with the importance of particular programmes, the choice of specific projects should be left in the main to the research workers themselves. This is, in fact, what is usually done. It is not so much a recommendation as an endorsement of accepted practice when we affirm that Directors should be given as much freedom as possible in determining the basic research programmes of their establishments, and that this freedom, with the reservations we have just made, should be delegated in turn to the research workers themselves.

95. At the same time, individual research workers and Directors, and their opposite numbers in Headquarters, should always be aware of the practical significance of the objective basic research which they encourage. This necessity is obvious—if not always achieved—in the case of applied research. If the factor of " relevance " is to be appreciated by those who encourage and who undertake objective basic research—and this criterion

of relevance is the main distinguishing feature between "objective" basic research and "pure" basic research—they must have the opportunity for direct personal contacts both with those concerned with related applied research and development, and with the ultimate user. This policy is, we understand, followed by, for example, the Agricultural Research Council, which encourages all its research staff, including those engaged on basic work, to establish personal contact with individual farmers as well as with the officers of the National Agricultural Advisory Service. Many and varied contacts have resulted, and we are informed that as a result the examination of agricultural research requirements, which is formally the responsibility of the Joint Committee of the A.R.C. and the Agricultural Improvement Councils, rarely brings to light problems of which A.R.C. research workers are not already aware.

96. From time to time, management may also need to bring a more positive influence to bear in the process of identifying the need for basic research and in determining programmes. For this purpose the techniques which are used by the Medical Research Council seem appropriate. As described in Chapter II, the Council each year considers a list of special topics to be reviewed in the following year at successive monthly meetings. We are told that the emphasis of these reviews is not so much on a retrospective report as on a survey of likely developments, seeking to foresee sources of new knowledge and opportunities for making useful advances.

97. Unfortunately, however, the main defect in certain fields does not seem to be a failure to identify the need for new knowledge and to arrange for the relevant work to be undertaken by a particular research organisation. For, while areas of ignorance may often be well recognised, any attempt to eliminate them may be frustrated by the lack of research workers willing to enter the field. A vicious circle then develops. An area of science which has been neglected and which lacks glamour will have few growing points to which research workers from other fields might be attracted, and thus becomes starved of the stimulus of the new men with new ideas essential for the creation of such growing points. In addition other factors may hinder the right kind of development. For example, the amount of dental research undertaken in this country is very small in relation to the cost of the dental services. The system of education and training for dentists does not seem to incline students towards research, and the financial rewards for dental practice are no doubt a powerful counter-attraction. Furthermore, those whose training in pure science (say, in physiology and biochemistry) leads naturally to a research career are unlikely to be attracted to research in dentistry, which may be thought to have a rather narrow range and to offer few obvious opportunities of achieving recognition in the academic world.

98. To some extent the same considerations apply to research on mental illness, where the need for a greater effort is now widely recognised. The M.R.C. has recently taken some steps to remedy the situation, and the proportion of its funds spent on mental research has doubled since 1956-57. But much remains to be done. For while research expenditure in this field

still amounts to little more than £200,000 a year, the mentally sick take up about half the hospital beds in the country.

99. These problems are certainly the concern of Government. But their solution is hardly just a matter of management. If unpopular fields of science of great social importance are to be dealt with effectively, all the Government organisations concerned will have to be judicious in their powers of persuasion and promises of financial assistance. If one cannot legislate for new ideas or "break-throughs", at least conditions can be provided which would allow them to be exploited if they occur.

REVIEW OF PROGRESS AND PROGRAMMES

100. Directors of establishments should be afforded as much freedom as possible in progressing their projects of basic research. Generally speaking, Headquarters control should be limited to the initial approval of the man-power requirements and the level of annual expenditure involved, and to the subsequent review of biennial or annual reports of progress. Where, however, basic research conducted by a Government Department is carried on in several establishments, the basic research programmes of the various establishments should also be brought together and effectively reviewed each year by the chief scientific adviser to the Department.

101. The programming of basic research thus places a heavy responsibility on Directors which cannot be delegated below their most senior staff. Moreover, it will involve the regular exercise of personal judgment on questions which can be posed only in terms of probabilities. It is of the nature of basic research that, generally speaking, neither complete success nor total failure is ever certain; nor can the rate of progress be forecast with any confidence. Nevertheless, if the "objective" character of Government-conducted basic research is to be maintained, and resources are to be used effectively, it is essential to review progress from time to time. To this end, we recommend that it should be accepted practice for Directors of research establishments to prepare rough time-tables when approving or reviewing programmes of basic research. A series of check points should then be agreed with the research workers concerned, and Directors should be systematic and rigorous in the reviews conducted at these agreed points.

102. Apart from the possibilities of control which such reviews provide, and the occasions they offer for discussion and guidance, these reviews serve two other important purposes. On the one hand, they can ensure that sufficient effort is being deployed where valuable results seem likely; for even in basic research the prospects of success may be increased by strengthening the staff engaged on the programme. Furthermore, when a "break-through" occurs, it may often be important to expand the work rapidly in order to bring forward the time when its application can be made effective. Staffing arrangements should be sufficiently flexible to assist these processes.

103. Correspondingly, periodic reviews should be used to ensure that resources are not being wasted on research where progress is unlikely because of the lack of new ideas or the necessary techniques. It may be difficult for a Director to terminate a basic research project without wounding

the *amour-propre* or shaking the confidence of some members of his staff. But this is an inescapable responsibility of management if the work of an establishment is to be directed to specific, even if broad, ends. To lessen the danger of frustrating the research-worker, however, it is always useful to allow those affected by a decision to bring their work on a project to an end reasonable time to write up and publish the work they have done—given that it merits this recognition.

104. The freedom given to the Director and his senior staff in determining the content and reviewing the progress of programmes of basic research makes it essential, in our view, to arrange for an independent review to be made from time to time by outside experts in the work covered by the particular establishment. The appropriate method will vary with the nature of the work of the establishment and with the organisation of which the establishment forms part. In the M.R.C., for example, where much of the work is of an "objective basic" character, such a review is carried out by the Council every three or so years on the basis of detailed progress reports by the Directors of research units (and by members of the Council's external staff working independently). In the A.R.C., reviews are made every five or six years by independent *ad hoc* Visiting Groups appointed by the Council and including user representation. We would not wish to lay down any general method; what is important is that such an independent review should take place every few years.

CHAPTER IV

APPLIED RESEARCH AND DEVELOPMENT: THE SELECTION OF PROJECTS

105. It is often said that British scientists are good at basic research and bad at developing their discoveries. Penicillin and radar (and even nuclear energy) are frequently used as illustrations of this generalisation. Other examples, no doubt, could easily be found. The charge is also made that we do not spend enough money on applied research or development, and that we do not attract enough of our best men to these aspects of scientific endeavour. This is partly due, so we are told, to the success of the Royal Society and the universities in building up the prestige of pure science, and partly to the failure of many employers—particularly those whose firms depend on the empirical development of craft techniques —to understand the part that applied science can and must play if their enterprises are to survive.

106. There is some truth in all these generalisations. The importance of applied research and development is certainly not widely enough appreciated, and we believe that the skills they demand tend to be underrated. While it is true that applied science usually breaks less new ground than does basic research, the qualities—personal as well as scientific—needed to make a success of an important piece of applied research or development are not less estimable, and no less rare, than are those which characterise the higher flights of basic research. Of many important and stimulating examples of applied research carried out in Government research organisations we would mention the development by the Safety in Mines Research Establishment of "foam plugs" as a fire fighting technique; the work on diffraction gratings at the National Physical Laboratory which has enabled the National Engineering Laboratory, in collaboration with industry, to improve the precision of control of machine tools; the production at Rothamsted Experimental Station of virus free plants of considerable practical application, e.g. a virus-free strain of King Edward potato with a yield ten per cent higher than the normal stock; and the opening up by the Post Office research staff of the possibilities of long-distance transmission using circular waveguides, whereby a large number of signals can be transmitted simultaneously through a guide of only a few inches in diameter.

107. Some industries—notably the aircraft, chemical and electrical industries—now devote large sums of money to applied research and development. Though the main effort of the universities is, and should be, on basic research, they also do a certain amount of applied research. The colleges of advanced technology, working closely with industry, also intend to develop work of this kind.

108. The Government has clearly got to keep an eye on the practical application of scientific discovery so as to stimulate where necessary, and to ensure that the scientific organisations which it finances are as effective as they should be in reaping the benefits of basic research. We are not satisfied that all this is being done as well as it could be.

109. At present Government organisations spend annually about £30 million on applied research and development for civil purposes, and employ on this work about 4,500 scientists and technologists. (These figures, which exclude the A.E.A., are derived from Tables I to IV of Chapter II.) D.S.I.R. and the A.E.A. are responsible for the larger proportion of the total of civil applied research and development which is wholly financed by Government. Our observations in this Chapter are therefore mainly focused on them, with special emphasis on the way the former manages applied research and the latter development work. What we have to say is, however, also relevant to some of the work of the other Research Councils and of a number of Government Departments, in particular, the Post Office, the Ministry of Agriculture and the Ministry of Power, as well as the Departments which are responsible for defence research and development.

110. As we have already said, the scientist engaged in basic research can generally follow his own bent. In applied research, and still more in development, both speed and the interests of the ultimate user of the work come more prominently into the picture. It is therefore with the relationship between the user and those responsible for the management of research that this Chapter is largely concerned.

111. Although the objective may be clear, the path of applied research and development is far from easy. This is especially so when circumstances exert continuous pressure on the potential user, forcing him to seek prematurely for "hardware" near the frontiers of knowledge. This is a common experience in the field of defence. It is equally so in certain civil fields, e.g. atomic reactor development. The satisfaction of some practical objective frequently requires new materials, new methods and perhaps even new technologies. New conditions emerge under which conventional materials or equipment have to be used, e.g. very high pressures or very low temperatures. Thus, estimates of effort and the rate of likely progress are often far from easy to forecast. It is inevitable that some projects will be started which in the end prove to be more costly, and which tie up more scarce manpower, than was envisaged when the decision to embark upon them was taken. While techniques of management should be designed to reduce uncertainties as far as possible, they cannot, by the very nature of the processes involved, always be successful.

112. Much of the work of D.S.I.R. consists of applied research, and many of its stations are concerned with a wide range of problems of interest to a variety of potential users. D.S.I.R. embarks relatively seldom on actual development, which is normally stimulated by the specific demands of a single user or group of users. On the other hand, the A.E.A., which is concerned with a much more homogeneous group of problems than D.S.I.R., devotes about one-third of its total civil effort to development.

113. The Atomic Energy Authority determines its research and development programme mainly by reference to the needs of four principal users or groups of users; first, the Ministry of Aviation for nuclear weapons; second, the electricity generating authorities for their nuclear power programmes; third, medical and agricultural authorities and industry for the production and use of radio-isotopes; and fourth, Government Departments and other organisations for health and safety problems associated with the use and transport of radioactive materials. The remaining research activities of the Authority cover all the other aspects of the general commitment "to produce, use and dispose of atomic energy and carry out research into any matters connected therewith", including work on controlled thermonuclear fusion.

114. The main projects in the programme of the A.E.A. are selected in the light of the needs of these various users, and the volume of supporting work is determined by the amount of basic research which experience suggests will be required to provide the necessary data. Selection and priorities of projects are determined by their relation to set objectives (e.g. the need to produce a power reactor of given performance) and to the time scale within which the objectives have to be met. In reactor development, where there is a limit to the number of directions in which resources can profitably be deployed, the Authority is advised by the Reactor Programme Committee, whose chairman is the Chairman of the Authority. Within the set policy on reactor development determined by the Authority, and subject to the responsibility of the Reactor Group Board of Management, the Development Policy Committee, chaired by the Member for Reactors, decides the action required and reviews progress. Other committees, or working parties dealing with particular aspects of the reactor systems being developed by the Authority, report to the Development Policy Committee. Lesser projects can be initiated by individual establishments, but only within the programme approved by the Authority, and subject to the approval of the Board of Management of the Group concerned. Through the Nuclear Power Collaboration Committee the Authority maintains close contact with the industrial consortia and with the electricity generating authorities.

115. The more varied responsibilities of D.S.I.R. make their problem of management far more complicated. The Council of D.S.I.R. forms its views of user requirements on the expressed or assumed needs of industry for the kind of information on which industry will base its own applied research and development work; on the research requirements which relate to public services such as roads and buildings; on the needs of the community generally in relation to such matters as air and water pollution, road safety, noise and fire control; and on the specific need of Government Departments for information which may affect administrative decisions. Proposals to open up some new field of research usually come from Directors of stations and their staffs, or from their advisory boards and committees, less frequently from the Council and its committees and headquarters staff. Proposals for new projects within an already established field of work come mainly from Directors and their staffs and advisory committees.

116. The pattern and scale of effort having been agreed by the Council, the Director of a station is given a large measure of freedom to determine the details of his programme and to support or stop subsidiary items of research. At some stations, Advisory Boards with a substantial membership of scientists and industrialists assist the Directors in formulating the general programme. In addition, there are close contacts between D.S.I.R. and its stations on the one hand, and industrial research associations on the other. As an experiment, the Council set up about two years ago small Steering Committees to bear the responsibility for the programmes of certain of its stations where special circumstances existed. These Steering Committees consist of a member of the Council, specialists from outside D.S.I.R., the Director of the station concerned, and other representatives of D.S.I.R. The member of Council or the Deputy Secretary of D.S.I.R. is usually the Chairman.

117. We understand that the purpose of these arrangements is to bring the user or potential user into contact with all levels of the organisation, from the laboratory bench to the Council itself. Potential users should therefore have the opportunity of playing their part in determining both the details of the programme of individual stations and the broad pattern of D.S.I.R.'s work.

118. Our considerations of these arrangements have stimulated us to spell out the obligations which fall on research establishments if they are to keep in adequate touch with other bodies engaged on related work and with those concerned with the application of their results. We have also tried to define the obligations which fall on potential users generally if they are to play a full part in maintaining an effective relationship with research establishments.

Obligations falling on Research Organisations

119. We consider that all Government organisations controlling establishments engaged in applied research and development should review their arrangements, both at Headquarters and at each of their research establishments, to see how far they provide satisfactory answers to the following questions:—

(a) Are they adequately informed of relevant research being done or planned in other Government research establishments, universities, colleges of technology, industrial research associations and individual firms; and do they encourage organisations outside the Government, either voluntarily or by extra-mural contracts, to fill in gaps in the over-all research effort relevant to their respective fields?

(b) Are contacts with the administrative and executive branches of Government Departments, as users or potential users, adequate in practice as well as on paper?

(c) Is their knowledge of industry sufficient to enable them to understand the user's business and to help him to formulate his needs for applied research?

120. Any shortcomings—especially under (b) and (c)—may make it desirable to arrange for secondment of some staff for short periods to administrative jobs in Government Departments, or to work in industry, in order to gain first-hand experience of what goes on "on the other side of the fence". This has been done occasionally. We recommend that the practice should be developed as part of a deliberately planned programme of training for selected staff.

121. One other aspect of the choice of projects is reflected in a recent innovation by the Council of Scientific and Industrial Research: we refer to the reviews undertaken by the Council's Economics Committee of the needs for research and development in the machine tool and shipbuilding industries. One of the main themes of our report is that Government research organisations, working in close collaboration with Government Departments, should keep themselves continuously informed about the crucial sectors of the national economy, establish the closest possible relationship with the users of research, assist them in identifying their needs, and help to persuade all the relevant agencies—universities, colleges of technology, Government research establishments, industrial research associations and individual firms—to play their part in meeting the needs disclosed. We therefore welcome these reviews by the Economics Committee and we recommend that D.S.I.R. should be supported in its intention to undertake others like them. We hope that such reviews will not be regarded as isolated operations but will, with the co-operation of industry, be carried out at appropriate intervals. As these reviews and the actions arising from them involve not only the Economics Committee and D.S.I.R. Headquarters but more than one of the Council's stations, and often require also the co-operation of other Government Departments, some problems of organisation may arise. We have been assured that D.S.I.R. is alive to this possibility.

OBLIGATIONS FALLING ON THE USERS

122. The users also have obligations to fulfil towards research organisations catering for their needs. Many industrialists serve on the councils and advisory boards and committees of D.S.I.R. and its stations. This service by individuals is to be commended, but we have the strong impression that in spite of these contacts, the needs of industry for, in particular, applied research are not always brought effectively to the notice of Government research organisations.

123. We therefore recommend that individual firms and the collective industrial organisations (employees as well as employers) should review the arrangements they have made to keep in touch with Government research establishments in the light of the following questions:

(a) On how many occasions during, say, the last three years have requirements been brought to the notice of Government research organisations?

(b) Is the machinery for formulating requirements satisfactory, and are there adequate links in this respect within the industry between those responsible for general policy and those responsible for research?

(c) Has consideration been given to the value, in certain circumstances, of seconding industrial research staff for limited periods to Government laboratories, i.e. making the arrangements we have suggested in paragraph 120 on a reciprocal basis.

124. To a greater or lesser extent, the work of all Government Departments is affected by advances in scientific knowledge; and there are some whose responsibilities are overwhelmingly scientific and technological (for example, the Ministry of Power and the Ministry of Agriculture, Fisheries and Food. In certain Departments many officials have scientific qualifications; while a few Departments also possess research establishments of their own. Differences in the responsibilities and organisation of Departments are so great, however, that there can be no single solution to the major problem of ensuring that full weight is given to scientific and technical matters in the formulation of Government policy.

125. In its first Annual Report*, published in 1948, the Advisory Council on Scientific Policy considered the general principles which should apply to the organisation of Government science. Having considered the increasing concern of Civil Departments with technical matters, the Council advised that (i) executive Departments should be responsible for identifying problems, settling their order of priority, deciding where the various investigations should be carried out and applying their results; and (ii) that the Research Councils and particularly the various stations of the Department of Scientific and Industrial Research should be free to initiate background research where they thought fit, "free from administrative control of the executive departments and consequently from considerations of day to day expediency". At the same time, the Research Council should also undertake research at the request of the executive Departments.

126. This advice has not always proved easy to apply, particularly in Departments whose technological interests are the primary concern of large research organisations not directly under their control. The need is, then, to integrate scientific staff of high quality with the administrative divisions of the Departments. The Ministry of Power illustrates the case. Except for its work on safety in mines, the Department carries out very little research on its own account, but is closely concerned with the scientific work conducted by the nationalised fuel industries. In order to discharge its overall responsibility, it has, therefore, seen to it that its own scientific staff works in the closest relation with the administrative staff of the Department. These arrangements are designed to enable the Ministry to bring a useful influence to bear on the speed and direction of the technical advances made by the industries with which it is concerned. The development groups of the Ministry of Education, to which we refer in Chapter IX, are an answer to a more special case of the same general problem.

127. We recommend, where the user or potential user of the results of research is a Government department which does not itself carry out research, that the Department should ask itself whether it has got the necessary machinery for formulating its requirements. In particular, Departments should consider whether sufficient scientific staff is integrated with the

* First Annual Report of the Advisory Council on Scientific Policy (1947–48); Cmd. 7455.

administrative divisions of the Department to ensure that it is able to take account of advances in the applications of scientific knowledge in the formulation of policy. We refer to this matter again in Chapter IX where we discuss the use of development groups.

128. Finally, on the general question of relations between users (or potential users) and research establishments, we would emphasize that it is not enough merely to establish particular forms of organisation. Successful collaboration between all the partners concerned depends as much on questions of personality and attitudes of mind as on specific techniques of management. Research staff must learn to appreciate the problems of the administrative and technical staff engaged on urgent matters of Government business and policy. At the same time, the user organisation must include staff who either themselves have experience of scientific research or have sufficient understanding of its potentialities to know when to look to the research establishments for help in assembling and analysing the data necessary for the formulation of future policy and for its efficient execution.

THE SELECTION OF INDIVIDUAL PROJECTS

129. When it comes to the choice of individual projects for applied research and development, we recommend that those responsible for the selection (or approval of the selection) should ask themselves the following questions:—

(a) Has there been close collaboration between the user and those responsible for research and development in agreeing requirements and priorities and defining them as specifically as possible?

(b) Could the requirements be met by using or adapting techniques, processes or equipment already in existence or under development either in this country or abroad?

(c) Is the project technically feasible within an acceptable period of time, having regard to the current state of scientific knowledge?

(d) Has the best possible estimate been made of the cost of completing the project by a given date in terms of money and scientific manpower? Would it be advantageous to investigate the project more closely, e.g. by way of a project study, as defined later in this report (Chapter VII, paragraph 200), before a final commitment is made?

(e) Is this the first project of its kind? And if so, has allowance been made for the inexperience of those carrying out the feasibility and project studies?

(f) Would the work be best done in a Government establishment or elsewhere? Are there, within Government, resources available (in particular, staff of the necessary competence) to carry out the project? If not, is the project important enough to justify recruiting extra staff and paying for extra equipment? Should the project be carried out under an extra-mural contract placed with industry or with a university or college of technology?

(g) Has the potential market—home or overseas—for the new equipment, technique or process been adequately considered?

(h) Where appropriate, has the estimated cost of producing the equipment or applying the technique or process, when developed, been taken into account? To what extent will industry have to learn to build up new manufacturing techniques?

CHAPTER V

APPLIED RESEARCH AND DEVELOPMENT: CONTROL OF PROGRAMMES AND DISSEMINATION OF RESULTS

130. We devote this Chapter mainly to the way programmes of applied research and development are controlled and we conclude with some remarks on the way the information they provide is disseminated. As in the preceding Chapter, we take as our principal illustrations the practices of the Department of Scientific and Industrial Research and the Atomic Energy Authority.

Control within Research Organisations

131. We suggested in Chapter III that control of objective basic research should be left as far as practicable to the discretion of the Directors of establishments, and that it should be largely confined to fixing ceilings of cost and manpower. In applied research and development, on the other hand, where goals can be more clearly defined, and where the results, if they are to be effective, may have to be achieved within a tight timetable, the techniques employed inevitably have to be more detailed and more rigorous.

132. Control procedure in D.S.I.R. is as follows. Each station annually sets out its research programme for submission by the Director to his Steering Committee or Board, together with the associated estimates of current and capital expenditure and manpower requirements. At this stage the programme is examined in a preliminary way at Headquarters. After the programme and estimates have been agreed by the Steering Committee or Board of the station, they are again examined at Headquarters, and submitted through the Council's Stations Committee to the Council for approval. In addition, each Director keeps his various projects under continuous review throughout the year; some stations have financial costing systems on the basis of which their Directors maintain a precise watch on expenditure on each project.

133. In the A.E.A. each of the five Groups prepares annual estimates based on the detailed budgets of their branches and establishments. These estimates, which are in effect budgets of the cash requirements of the Groups for the following year, are brought together and examined by the Authority, which then allocates funds to the Groups on the basis of the estimates as approved. Group expenditure is reviewed at quarterly intervals by the Member for Finance and Administration who, in addition, receives monthly accounts of any major variations of expenditure or receipts as compared with the agreed budget, and also separate quarterly reports on the progress of capital schemes of £1 million or more.

134. The Board of Management of each Group exercises general financial control of the Group budget. The branches and establishments in the Group are responsible for controlling expenditure within their allocations in accordance with their approved programmes. Budget approval does not, however, give authority to start capital schemes. In each case capital items have to be approved by the Group Board, who themselves have to obtain approval from Headquarters in London for, in general, items costing over £50,000, and who make a quarterly review of the costs and progress of capital projects against the provision made. The Boards of each Group are provided with regular information on costs, manpower deployment and progress in relation to target dates for all the Group's projects.

135. Not surprisingly, the Authority finds that closer control is desirable and possible for projects supporting or leading to specific items of design or construction (i.e. development work) than for general research projects or basic research. We think that the procedure of control worked out, for example, for the Authority's Reactor Group is of general interest and we describe it in detail in Appendix III. Briefly, the Development Policy Committee of the Reactor Group approves each year a programme which identifies the main projects on which the Group is engaged. Each of these is broken down into sub-divisions and, for each sub-division, tasks are allotted to establishments, where they are further divided into jobs and costed in terms of manpower as well as money (covering both capital and current work). These costed jobs are built up into the annual Cash Budget of the Group for submission to the Authority after approval by the Group Board of Management. When approved, each establishment is given a budget for the next financial year. The actual expenditure and manpower engaged on each job is recorded as part of the general commercial costing procedure of the Authority. The progress of the work against programmes and budgets is considered at various management levels at agreed review dates, concurrently with statements of costs (covering both current and capital expenditure) designed to highlight variations from agreed authorizations based on the various budgets.

136. These procedures, by which D.S.I.R. and the A.E.A. control the resources that are expended in applied research and development, seem to us satisfactory in principle and, so far as our information goes, they are adequate in practice.

137. They show that any progressing system for projects of applied research, whether carried out within a Government establishment or extra-murally under contract, needs to be based on an agreed plan, whose broad outline should have been worked out before the project is embarked upon. The plan should set out technical goals, an agreed scale of effort (expressed in terms both of money and manpower), and target dates for the completion of important parts of the project, as well as for the project as a whole. The essential features of any such system are a review at regular intervals of the technical progress of the work, of the effort expended, and of likely progress. Since circumstances affecting the need for the work can change, the original considerations which led to the decision to embark on the project should also be periodically reviewed.

138. We recommend that, in the control of applied research or development, an assessment of results achieved and of likely future progress should always be carried out concurrently with a review of expenditure to date and estimated future costs. Such dual assessments should be undertaken at intervals of not more than three to six months, and the results should be made available not only to higher management but also, as a way of encouraging cost-consciousness, to those who are directly responsible for individual projects, i.e. down to Principal Scientific Officer level, or possibly lower.

139. The extent to which detailed records are kept of the resources involved in individual projects, both in terms of money (e.g. staff salaries, overheads, capital expenditure) or manpower (e.g. man-hours or numbers of staff by grades) will vary with the nature of the project, and can be determined only by those directly concerned with the management of the programme. These records must, of course, be detailed enough to provide project leaders with a realistic picture of what is happening. The pendulum can, however, swing too far, and care must be exercised lest records become so detailed as to be excessively time-consuming and irritating to those concerned, at the same time as they give a false impression of accuracy.

140. We recommend that Departments and Research Councils whose research establishments do not review their work in the way suggested above should consider ways and means of devising regular reviews on these lines. Where work is already supervised in this way, methods should be reviewed to see whether they can be simplified.

141. In addition, the whole programme of an establishment, including any extra-mural work, should be reviewed at least once a year by the Director in collaboration with any Steering Group or Advisory Body (or Headquarters organisation) responsible for assisting him in carrying out the remit of his establishment. Such reviews should contain the same elements as we have suggested above for reviews of individual projects but on a broader basis, e.g. by sub-programmes or groups of projects.

142. Apart from more general reviews of the work of individual establishments which are the responsibility of the parent Department or Research Council, there is a great deal to be said (especially in relation to the problem of deciding whether particular projects are worth continuing) for a review of the work of individual research establishments every five years or so by an independent group of specialists. As we have already mentioned, such a system is used by the Agricultural Research Council, and in a modified form by the Medical Research Council. We return to this question in paragraphs 253 and 256 of Chapter IX where we recommend that this technique be more generally adopted.

143. Most Government organisations undertaking research usually control their total research expenditure (both recurrent and non-recurrent) through a system of annual estimates which cover both finance and manpower requirements. Some organisations are able, or are required, to work in a more extended time-scale. For example, research organisations for which the Ministry of Works provides buildings are invited to collaborate

with the Ministry in making provisional estimates of their requirements for five years ahead. D.S.I.R. also used to operate on a quinquennial system for recurrent expenditure, in much the same way as does the University Grants Committee. This has now been changed. Each year D.S.I.R. agrees with the Treasury a firm estimate for the coming year, and provisional but reasonably firm estimates for a further two years, as well as more tentative "forward look" figures for two more years. In view of the wide range of the Department's commitments and the uncertainties of research and development, this seems to us preferable to the old quinquennial grant.

Treasury Control of Research and Development

144. The extent to which the Treasury exercises detailed financial (and other) controls over the resources devoted by the Government to research and development varies from case to case. Control is most detailed for Government Departments financed by Parliamentary Vote (which includes D.S.I.R.), but is exercised in broader terms over the A.E.A. which, although financed by Vote, is in other respects a public corporation organised on a near-commercial basis. Treasury control of organisations which receive grants-in-aid is as a rule restricted to agreeing policy and negotiating the size of the annual grant for the organisation concerned. These differences reflect differences in the statutory or constitutional position of the organisations, and correspondingly in the degree of their public accountability.

145. The main features of Treasury control of expenditure on research and development—as, indeed, of Treasury control of most Government activities—can be set out under three heads. First, Treasury approval is required for all new items of expenditure or for changes in policy that require new expenditure, subject to any delegated authority which may have been given to particular organisations in particular fields of expenditure. Second, the Treasury determines, in consultation with the Department or organisation concerned, the total effort to be expended each year in terms of both money and manpower, and ensures, as far as it can, that the annual estimates of expenditure on individual items making up the agreed total are realistic, and that the programme as a whole and any major projects are consistent with the general policy and future commitments of the Department or organisation. Third, the Treasury exercises detailed control over the rates of pay of all staff employed by Government Departments, including D.S.I.R., and has an agreed policy with each Research Council and with the A.E.A. in respect of their staff.

146. The Defence Budget (for which the Minister of Defence is responsible) always includes a specific figure for research and development. In the civil field, there is no single research and development budget. The several divisions of the Treasury which are concerned with Departmental expenditure collaborate with individual Departments and organisations in the examination of separate annual estimates for expenditure on research and development.

147. Lay officials in the Treasury who are concerned in this work must inevitably tend to focus their attention on new major projects, on new fields of research, or on unforeseen increased expenditure on old projects,

and less on the elimination of existing items because they have declined in importance. There is little more Treasury officials can do, either on the basis of their own experience or in the light of their detached rôle. Organisations responsible for research and development have therefore a special responsibility for ensuring that all the existing items in their programmes are critically reviewed at regular intervals from the point of view of their continued technical relevance.

148. The Treasury has devised useful techniques for examining research and development programmes, and in particular for applying a critical scrutiny to large individual projects (frequently involving many considerations other than purely technical ones). In this respect it has a valuable function to perform. But the Treasury will always have to depend on the technical experts at the headquarters of Departments and other organisations for the scientific and technical appraisal of the programmes they approve and for their proper execution. It should, therefore, always be in a position to assure itself that Departments and other organisations have the necessary machinery for examining the contents of their research and development programmes critically, for carrying them out, and for reviewing progress. This, it seems to us, is much the most effective contribution that the Treasury can make to the control of public expenditure on research and development.

Delegation

149. Needless to say, the discharge of this central responsibility by the Treasury needs to be associated with that degree of delegation of financial authority to Departments and Research Councils which will obviate unnecessary delays in the carrying out of new work. In general, we favour as much delegation as is practicable. It is a fallacy to suppose that the greater the extent to which higher levels of administration concern themselves with cost control the less will be the risk of wasting public money. The aim should be to make those who are responsible for the actual work more cost-conscious.

150. We think that Departments and Research Councils should be able, and should be compelled, to look more than one year ahead, not only in formulating their research programmes but also in their budgeting. This can be achieved in one of two ways. The first is what may be called the "rolling three-year grant".* This has two advantages: both the Treasury and the organisation receiving the grant always know where they stand for three years ahead and, when considering any new projects proposed by its constituent units, the receiving organisation can examine them in a forward as well as in an immediate financial context. The second method is the one recently adopted by D.S.I.R., as described in paragraph 143, and may be thought to give greater freedom to adapt programmes to changing circumstances. We certainly attach importance to the "forward look"

* This system works as follows. In year x the Treasury negotiates a grant for each of the years x+1, x+2 and x+3. These grants are not subject to modification unless exceptional circumstances arise. In the year x+1 a grant for year x+4 is settled, and in year x+2 a grant for year x+5, and so on.

up to five years ahead, and we think there is much to be said for combining a firm estimate for the coming year with a fairly firm estimate for the following two years and a "forward look" at the two years after. Indeed, there will occasionally be advantages in looking as far as ten years ahead, particularly when programmes of research and development involve scarce scientific manpower and expensive facilities.

151. So far we have been dealing with total research programmes. In the case of individual projects the Treasury delegates power of approval in varying degrees to different organisations and in respect of different types of project. We have received no representations from Departments or Research Councils suggesting that the extent of the delegation should be increased.

152. It has, however, been suggested to us that, if Directors of research establishments were to be given, by their parent institution, greater day-to-day financial discretion within an approved total annual estimate, the greater cost-consciousness which would be engendered would provide an incentive to improve their general housekeeping and that consequently more money would be devoted to research. Transferring a surplus in this way from one account to another is not, we think, acceptable in a publicly financed organisation. But there may be cases in which the number of sub-heads of control could usefully be reduced so as to give Directors greater freedom of manoeuvre and we recommend that the organisations concerned should consider what could be done to achieve this.

153. Formal delegation of financial authority by the Directors to members of their staff who are heads of Divisions may be impracticable. But, as we have suggested above, we feel that Directors should do all they can to make their senior staff cost-conscious without impeding their liberty to work. Research staff should always be involved in the periodical assessment of the progress of individual projects and in the check on money and manpower which they entail.

154. Properly used, the techniques that have been devised to set research programmes into the type of "rolling" five-year plan recently adopted by D.S.I.R. could make everyone's task easier. Any new project which comes up could then be considered within a wider framework so that the number of occasions on which the sponsoring Department, or the Director of an establishment, or the head of a Division of an establishment, has to review his own priorities, would automatically increase. This we regard as all to the good; for a common defect of the present procedure is that the supervising authority, whether it be the Director of an establishment, a Headquarters organisation, or the Treasury, has to argue the merits of a particular new project more or less in a financial vacuum. The result too often is that the examiner does not say that the idea is so bad that it must be rejected out of hand, or so good that it must immediately be accepted. He tries to consider it "on its merits", and in the end he usually approves it, subject to some reduction in the estimate. Nothing is said about the effect on other projects of approving this new one, or of the effect on the progress of the new project of cutting the estimate.

155. A determination to delegate financial responsibility as far down the line as is practicable, coupled with the type of "rolling" five-year plan now adopted by D.S.I.R., could, we believe, help significantly to increase financial efficiency and at the same time improve relationships between the man doing the research, and those whom he is inclined to think of as remote and un-understanding financial task-masters.

Dissemination of the Results of Research

156. We can only touch upon the difficulties which the dissemination of new scientific information entails. They are the subject of continuous discussion and examination, both nationally and internationally. The question for us is how Government research establishments, subject to security requirements in the case of defence research, can assure themselves that the results of their work are made available in a suitable form to all concerned.

157. The way a potential user of new information can be kept in the picture varies, of course, with the nature of the research and of its possible applications. The close contacts which the M.R.C. and its units maintain with teaching hospitals, Government Departments concerned with health, and pharmaceutical firms, appear to ensure that the results of medical research are readily made available. In agriculture, the National Agricultural Advisory Service plays an important role in making known the work of, for example, the A.R.C. through personal contacts, lectures, demonstrations and the written word. The task facing the A.E.A. of making research results available will no doubt increase with the growth of research and development on atomic energy within industry.

158. The problem is, in theory, simple in defence, because of the close relationship between the user and the research establishments concerned. But the results of defence research and development often have important applications in the civil field. The exchange of information undoubtedly takes place most effectively where individual firms concerned in civil work also have defence contracts, and where close links exist at the working level. Certain of D.S.I.R.'s stations have similar contacts with defence research establishments for whom they may carry out research on a repayment basis. D.S.I.R. Headquarters receives lists of unclassified reports produced by defence research establishments, and selections from these lists are passed on at regular intervals to the Department's stations, the industrial research associations and some nationalised industries. Copies of the original reports are made available to those who ask for them. The Service and Supply Departments also keep a watch for patentable developments arising from the work of their own research establishments. Most of these are passed on to the National Research Development Corporation or Power Jets (R and D) Ltd. for exploitation.

159. The responsibility for seeing that industry, in general, is informed about the work going on in Government laboratories rests largely with D.S.I.R. An Information Division of D.S.I.R. Headquarters deals with this problem, with branch offices in Cardiff and Edinburgh. D.S.I.R. also "grant-aids" a number of regional technical information centres. In addition, the dissemination of technical information is the primary responsibility of

certain members of the senior staff of individual stations. D.S.I.R.'s problem is a complex one, in that its own researches and those of the industrial research associations cover a wide range of industries whose structure and research and development activities vary considerably.

160. The central part of D.S.I.R.'s problem is the need to convey the results of research in a form which points the way to its practical application. In view of this, we should like to draw attention, as a useful model of what can be done, to the work of the agency set up in 1940 by the Royal Aeronautical Society to collect, correlate and distribute research data. We understand that the "data sheets" prepared by this agency have not only been of great value to those who are concerned in the design and development of aircraft, but have been sought after by those working on similar scientific and technical problems in other industries. The preparation of authoritative designs and analytical charts is an important activity in the research-design-production sequence which can be carried out effectively only by a central agency.

161. D.S.I.R., its stations, and some of the industrial research associations have already undertaken corresponding work on a number of particular topics. For example, the National Engineering Laboratory is acting as a centre for collating and publishing information on "creep" processes relevant to the use of materials at high temperatures; and the National Engineering Laboratory has compiled data on high temperature steam for use in the design of steam turbines. Other D.S.I.R. stations are collating and publishing information on such industrial processes as heating and drying, and crushing and grinding; and the Building Research Station has produced design data relating to the thermal insulation of buildings. The subjects selected for this treatment are those where there is a need for knowledge in a readily assimilable form. In our view, there is room for much more work of this kind both by D.S.I.R. and the industrial research associations. We hope, for example, that the projected Machine Tools Research Association will consider the problem of providing information on the design of machine tools in the form of data sheets.

162. Data sheets are an appropriate medium where the information is for the use of comparatively large groups which are engaged on design and development work. Other methods of presentation are preferable in the case of smaller firms. But whatever way the job is done, positive efforts to disseminate information are essential if the resources devoted to research and development are to be properly used. Furthermore, data sheets, leaflets, or any other form of written material are not enough. They must be backed by personal contacts of all kinds. These are especially important in the case of small businesses—as the experience and success of the N.A.A.S. has shown in the case of the farmer. The regional technical information centres "grant-aided" by D.S.I.R. are of particular value for this purpose. We therefore hope that D.S.I.R. will be encouraged to carry on with this support, preferably in association with local industrial concerns and, where appropriate, colleges of technology.

Defence Research and Development

CHAPTER VI

ORGANISATION OF DEFENCE RESEARCH

163. Recent estimates of Government expenditure (1960-61) show that about £240 million* is allocated annually to research and development to meet the needs of the armed services. As we have already noted there has been much public concern about the way this sum, which represents about three-quarters of all the money that the Government spends on all forms of research and development, is controlled. This has been partly because of the heavy cost of a certain number of projects which have proved abortive, and partly because the cost of many others has turned out to be far greater than was assumed when they were started. Some of the lessons of past errors have already been learnt, but we think that further important improvements in administration can be achieved.

The Nature of Defence Research and Development

164. The responsibility of those who control defence research and development is to ensure, to the extent that our national resources allow, that our armed forces are abreast technologically with the military threat that our potential enemies pose. In discharging this responsibility it is both natural and prudent for them to assume that the U.S.S.R., the leader of the Eastern bloc of nations, is as far advanced scientifically and technologically as is the West, and that it is equally concerned to mobilize the most sophisticated scientific and engineering knowledge in the equipment of its armed forces.

165. Defence technology depends on the same basic scientific knowledge as does civil technology. As in the civil field, too, research and development specifically carried out for defence can be divided into three broad categories: basic research, applied research, and development. The basic research, nearly all of which is done in Government establishments, accounts for only about £2 million a year, but its relative importance far exceeds its cost. Though some of it is not directed specifically to meeting immediate Service requirements, all contributes to the fund of knowledge needed to meet likely requirements of the future.

166. Most of the applied research, on which roughly £45 million is spent annually, is also done in Government establishments. This leaves about £190 million devoted to development; of this about £175 million is spent, by way of extra-mural contracts, in industry. Thus, by far the most costly component of defence research and development is not the gaining of basic and applied scientific knowledge but the transformation by industry of that knowledge into weapons systems.

* Exclusive of the undisclosed annual expenditure for defence of the Atomic Energy Authority.

167. Most of the money that this work entails is devoted to the development of a relatively small number of guided weapons and aircraft. This underlines the first and most important problem in the control of defence research and development, namely, the manner in which projects are selected for development out of the many which are put forward by the Services. The second important issue is the technical and financial supervision of projects once they have been embarked upon. The organisation, manning and control of Government research establishments concerned with defence represents the least difficult part of the problem.

168. Before these issues are discussed in detail, we would point out that the monetary and manpower resources which defence research and development command, both within and outside Government establishments, are always stretched. Furthermore, since the major projects on which staff are now working are not likely, on average, to be completed before at least five years, the programme at any given moment is necessarily characterised by a large element of rigidity. It is inevitable that the bulk of the current programme should reflect past decisions rather than those which might be taken today.

THE CENTRAL ORGANISATION FOR DEFENCE

169. The responsibilities of the Minister of Defence and his relations with Service Ministers and the Minister of Supply (now the Minister of Aviation) are set out in the White Paper on the Central Organisation for Defence published in July, 1958 (Cmnd. 476).

170. The Minister of Defence is "in charge of the formulation and general application of a unified policy relating to the Armed Forces of the Crown as a whole and their requirements". In the discharge of that responsibility the Minister of Defence has authority to decide (subject to the responsibilities of the Cabinet and its Defence Committee) all major matters of defence policy affecting, among other things, defence research and development. He also has the duty to take, after consultation with the Service Ministers concerned, "all practicable steps to secure the most efficient and economical performance of functions common to two or more of the Services".

171. Within the limits of policy determined by the Minister of Defence, the Service Ministers, working through the Board of Admiralty and the Army and Air Councils, are responsible for the efficiency and administration of the three Services. The Minister of Aviation, similarly, is responsible for the efficient execution of approved programmes of defence research and development and production other than those which are the responsibility of the War Office and the Admiralty (see below).

172. When the Service Ministers or the Minister of Aviation wish to make proposals on any matter affecting defence policy they will normally submit them to the Minister of Defence. This arrangement does not, however, prejudice their constitutional right to make direct submissions to the Cabinet and its Defence Committee.

173. The Chief of the Defence Staff, together with the Chief of Naval Staff, the Chief of the Imperial General Staff, and the Chief of the Air Staff, form the Chiefs of Staff Committee, of which the Chief of the Defence Staff is the Chairman. This Committee is collectively responsible to the Government for professional advice on strategy and military operations and on the military implications of defence policy generally. The Chairman of the Chiefs of Staff is responsible to the Minister of Defence and is his principal military adviser. In addition, the Chiefs of Staff are responsible, through their Chairman, to the Minister of Defence for the conduct of military operations. Each of them, however, also has at all times a right of direct access to the Minister of Defence and, where necessary, to the Prime Minister, whether on operational or other military matters; and, in addition to their attendance at meetings of the Defence Committee, they may be invited to attend meetings of the full Cabinet.

The Role of the Ministry of Defence

174. The Ministry of Defence is responsible for the Defence Budget as a whole, including research and development. Each year the Ministry obtains forward estimates of defence expenditure from the Service Departments and the Ministry of Aviation and, in consultation with the Treasury, sets a target figure for each Department's total defence expenditure during the next financial year in the light of the money expected to be available. This total includes a separate figure for research and development. As part of this annual exercise a "forward look" is taken of expenditure covering five years ahead. In this way the Ministry of Defence exercises general supervision of research and development expenditure in the defence field.

175. As part of its general supervisory responsibility, the Ministry of Defence allocates resources between the three Services. In the case of research and development this responsibility is exercised through the Defence Research Policy Committee (D.R.P.C.). This Committee is under the chairmanship of the Chief Scientific Adviser to the Minister of Defence, and includes representatives of the Chiefs of Staff, their Scientific Advisers, and the Controllers responsible for research and development in the Service Departments and in the Ministry of Aviation.

176. Research and development projects arising from the operational requirements of the Service Departments which, if accepted, would be expected to make a substantial claim on resources, or which imply important or controversial decisions of defence policy, are considered and given priorities by the D.R.P.C. within the framework of current defence policy and within the context of the overall defence research and development programme. Projects which do not fall into the above categories have also to be submitted, but the D.R.P.C. has delegated to its official staff, called the Defence Research Policy Staff, the responsibility for their examination. (The functions of the D.R.P.C. and its Staff are further described in Chapter VIII, paragraphs 228 to 232.)

THE RESPONSIBILITIES OF THE SERVICE DEPARTMENTS AND THE MINISTRY OF AVIATION

177. The three Service Departments—the Admiralty, Air Ministry and War Office—are each responsible for formulating their own operational requirements within the operational plans of the Chiefs of Staff and in accordance with the Government's defence policy. There are, however, considerable differences between the direct responsibilities of each for carrying out research and development or for production and supply. Since 1959, when the Ministry of Supply was abolished, and the Ministry became the Ministry of Aviation, the responsibilities of Departments have been as follows.

178. The Admiralty is itself responsible for research and development and for the production and supply of the majority of its own requirements, in particular those relating to naval vessels and their associated conventional weapons and equipment. In addition, the Admiralty carries out research and development on electronic valves on behalf of all three Services. Admiralty requirements for aircraft, guided weapons and associated radar, radio and electronic equipment are, however, dealt with by the Ministry of Aviation.

179. The Air Ministry has no supply functions, and its research and development responsibilities are restricted to operational research, aviation medicine and, since the Ministry is responsible for the Meteorological Office, for meteorology. Its requirements for aircraft and guided weapons and their associated equipment are met by the Ministry of Aviation, and its other requirements by either the Admiralty or the War Office.

180. The War Office is responsible for the research and development necessary to meet a large proportion of its own requirements and also for their supply, and has similar responsibilities for meeting the joint requirements of the three Services for conventional weapons and ammunition, vehicles, clothing and general stores. Like the other two Service Departments, the War Office passes its requirements for aircraft, guided weapons, radar, radio and electronic equipment to the Ministry of Aviation.

181. The Ministry of Aviation is responsible for the research and development necessary to meet the requirements of the three Services in respect of aircraft and airborne weapons and equipment, atomic and guided weapons, and associated radar and electronic equipment generally, and for the production and supply of such weapons and equipment. (The 1959 changes also involved the taking over by the Ministry of the responsibilities for civil aviation previously exercised by the Ministry of Transport and Civil Aviation, which was then renamed the Ministry of Transport.)

182. In the next chapter we examine in detail the various stages leading to the placing of a development contract, but it may be helpful to end this factual review by summarising the procedure here. The Service and Supply Departments are always thinking up new ways of improving weapons and instruments, and the initial formulation of requirements (Staff Targets) by the sponsoring divisions of the Service Departments

occurs informally through contacts between them and the Headquarters of the research and development authority (which may in some instances be another division of the same Service Department). At this stage of the process the Scientific Advisers of the Service Departments and the Chief Scientist of the Ministry of Aviation play an important role. Apart from advice given on particular proposals, these senior scientists have a continuing responsibility for ensuring that a fund of scientific knowledge and resources is built up to sustain the development of future generations of weapons. There are also contacts between the staff of the establishments of the research and development authority and Service technical personnel who are attached to them from the Headquarters of the Service Departments. These informal arrangements result in operational requirements being agreed between the sponsoring division of the Service Department and the research and development authority. These are then formally approved (as Admiralty Staff Requirements; War Office Policy Statements and General Staff Operational Requirements; and Air Ministry Operational Requirements) by the highest authority in the Service Department, i.e. by the Board of Admiralty, by the Army Council and by the Air Council. They are then formally accepted by the Supply Authority as being feasible and capable of being met by the agreed time within the resources likely to be available. The requirements are then put to the Defence Research Policy Committee where appropriate, and, if agreed, Treasury approval for expenditure on consequent research and development is sought either by the Service Department or by the Ministry of Aviation.

CHAPTER VII

THE SELECTION AND CONTROL OF PROJECTS

183. In this Chapter of our report we are concerned with the procedures required for the initiation and effective management of large research and development projects. These procedures cover not only central control and interdepartmental co-ordination with which we have been mainly concerned, but matters which are the internal responsibility of the supply departments, i.e. the Admiralty, the Ministry of Aviation and the War Office. As regards the latter we wish to make it clear that at the time we ourselves were taking evidence on this aspect of our remit, much was being done by the departments concerned, and in particular by the former Ministry of Supply and later by the Ministry of Aviation, to develop procedures for more effective departmental control of these projects. The purely departmental procedures discussed in this Chapter are, to a considerable extent, already current practice.

184. Most large research and development projects fall in the defence field, and we therefore deal with the problem of their control in this section of the report. But similar procedures are required for the initiation and management of civil research and development projects. Our recommendations are therefore addressed not only to the three departments concerned with defence but also to those civil government organisations which may from time to time be involved in substantial research and development projects.

185. There is no single system of processing which is applied to defence projects in the interval between their conception and the moment they become the basis of a development contract. Even though complete uniformity may be impossible to attain, much is, in our view, gained by distinguishing clearly the following steps in the process:

(i) the formulation of a draft operational requirement (Staff Target), followed at an appropriate stage by an agreed operational requirement and the initial sketch of a technical specification ;

(ii) a feasibility study ;

(iii) a project study, often in the form of an extra-mural contract ;

(iv) where necessary, a " holding " contract ;

(v) a development contract, usually in the form of an extra-mural contract.

Not all these steps need be used for every project, but those that are used should be clearly defined and formally recognised. For example, in the case of a small, technically simple project, the Supply Department concerned might decide, once the operational requirement had been properly formulated, that there was no difficulty about letting a satisfactory development contract. There would be no need for a feasibility study ; the project study would consist simply of a brief assessment within the Department ;

and no question of a project-study contract or a holding contract would arise. All that would be required would be a record of the fact that the missing stages had been passed over because the necessary information already existed. On the other hand, a major and successful project involving, say, the development of a new guided-weapon system would, in our view, certainly necessitate the precise distinction and negotiation of all the five stages which we have defined.

186. The rest of this Chapter is concerned with major projects, since they are the most important in the whole programme of defence research and development. Few of the older projects now under development have, in fact, passed through all these stages or, if they have done so, the stages have not been as clearly defined as we think they should be. The aim must be to impart continuous momentum to successful projects, and to enable a clear decision to be obtained at an early stage not to proceed with any project which does not stand up to critical review. We do not think that a risk of false economy is created by more formal definition of the stages referred to in the preceding paragraph—for example, a risk of delaying the development of a weapon system. On the contrary, in our view a firmer definition of the stages through which major contracts must pass will normally result in the more rapid completion of successful projects at a lower cost to the public.

The Operational Requirement

187. Any administrative system concerned with the equipment of our Armed Forces should be based upon a reasonable conception of the military threat by which the country may be faced at the time the equipment is likely to become operational, and upon a clear conception of national strategy both in the economic and political fields.

188. The process of developing a new weapon system may begin either with an Intelligence appreciation of some new threat or as a technical idea generated anywhere within the chain of our defence establishments, from the Service Ministries right down to a bench in some research laboratory, either inside or outside Government. If it begins as an Intelligence appreciation it is essential that the group preparing the appreciation should include men with appropriate scientific and technical experience.

189. As the concept of a project begins to assume precision, it may become a Staff Target which, as it becomes further elaborated, transforms itself into an Operational Requirement of the Service Department concerned. During this process, the basic research carried out in, and the general scientific and technical knowledge of, the research establishments of the Ministry of Aviation, the Admiralty and the War Office is continuously confronted with the operational experience of the military staffs concerned.

190. In the light of the representations made to us, we see the function of the Service Staffs at this stage as that of defining what their requirements are, and the function of the Supply Departments and establishments responsible for research and development as that of indicating how these requirements can be met. Some appreciation of our own and the enemies'

technical capacity is essential if the military are to play a proper part in this joint process; and a sympathetic understanding of what is possible in military practice is clearly required of the scientist and the engineer. This kind of interaction will always tend to operate at the extremes of technological knowledge, whether our own, our allies' or our enemies'. It always needs to be tempered with a sense of scientific as well as economic proportion.

191. The process of elaborating an operational requirement is the least costly phase in defence research and development. New ideas should always be freely encouraged at this stage, since without them the imagination of those concerned would become dulled and the equipment of our armed forces would become out of date in relation to that of other Powers. On the other hand, some control over their growth is required, for what begins as a small idea may end up as a very ambitious and over-elaborate project, which, if adopted, might transform national strategy not only in unpredictable, but perhaps also in militarily unnecessary and economically unsupportable, directions. The Operational Requirement is thus a most important document in the formulation of a research and development project. It should stimulate the scientific experts to produce the best equipment in the time available but should not set operational targets unnecesarily high, and so lead to expensive and time-wasting scientific and technical work. In meeting the ever-changing operational needs, the best is too often the enemy of the good. In our view the assessment of the Operational Requirement of some very costly projects has not always been as critical from the technical point of view as it could have been. Nor has unnecessary inter-Service or international duplication always been avoided; we refer to these matters later.

192. As we have said, the central part of the concept of an operational requirement may germinate anywhere. On the other hand, the responsibility within each Service Ministry for its precise formulation is in the hands of one or two senior officers, such, for example, as the Deputy Chief of Air Staff in the Air Ministry and, under him, the Assistant Chief of Air Staff in Charge of Operational Requirements. An immense responsibility rests on the shoulders of these officers and they cannot, in our view, fully discharge this responsibility, bearing in mind the great complexity of modern weapons and equipments, without experience of scientific and technical as well as operational matters.

193. Since General Duties Officers who reach high rank in the Services are rarely university graduates in either basic or applied science, the only way they can gain technical experience is through prolonged familiarity with the technological problems concerned in the development of modern weapon systems. We therefore share the disquiet expressed by the Select Committee on Estimates, which recently reported* on the Headquarters organisation of the Admiralty, about the short tours of duty of senior officers in these responsible positions. They are generally so short that it is most unlikely that any single officer will have the opportunity of seeing

* Select Committee on Estimates, Session 1959–60; The Admiralty Headquarters Organisation.

a major project pass through the more important stages of its development. Lack of personal continuity in the higher positions from which operational requirements are controlled is bound to have its effect on much of the research and development designed to meet the requirements of the Services. We recommend that this matter be urgently reviewed by the Board of Admiralty, and the Army and Air Councils respectively, to see whether this particular difficulty can be minimised. With the increasing complexity of weapons systems it is worth considering whether the occupants of the posts concerned should not be chosen from the technical streams of the Services more frequently than is the case.

194. The quality of the Directors of the scientific Headquarters staffs of the Admiralty, War Office and the Air Ministry, of the Directors of research establishments for which they are responsible, and of the more senior scientific staff in the Ministry of Aviation, is also of the utmost importance in this respect. All who share the task of defining an operational requirement must not only have a clear conception of what is technically feasible, but should also be in a position to appreciate what is financially sensible in the light of the objectives that underlie the particular projects on which they are called to advise. As their experience in other fields increases, it is inevitable that scientists who are translated from research establishments to a Headquarters organisation should become less in touch with technical matters than their colleagues who remain behind. We recommend, therefore, that the research staff in establishments should have an appropriate formal association with the process of evolving operational requirements. We also recommend that the interchange between scientists in Headquarters posts and scientists in defence research and development establishments should be freer than is often the case. The possibility of reducing the financial disincentives that undoubtedly exist, because, for example, of the high cost of living in London, should be examined.

Feasibility Studies

195. Depending upon the nature of the technical project to which it will relate, the definition of an operational requirement may be simple or may prove a difficult and prolonged process. However long it takes and whichever way it is effected, the elaboration of the operational requirement and of its corresponding technical specification tend to run in parallel. A fairly clear idea may quickly emerge of the technical specification and of the cost of the development of a simple project, but with a complex weapon system a great deal of work will be required before its technical feasibility can be satisfactorily assessed and a broad estimate of its probable cost can be made.

196. Not surprisingly, procedures for drawing up technical specifications vary both between and within Departments. Except for aircraft and guided missiles, the Admiralty, as we have already stated, is its own Supply Department. With the transformation of the old Ministry of Supply into the Ministry of Aviation, this is now also true, with some exceptions, of the War Office. The Air Ministry, on the other hand, depends on the Ministry of Aviation for the satisfaction of all its needs in aircraft and weapons, an arrangement which separates it from direct responsibility for research

and development. This has its disadvantages, but we appreciate that this is a complex question, and we have not investigated the merits or demerits of possible alternatives. To do so would take us well outside our terms of reference.

197. The scientific and technical facilities available to each of the Service Departments are sufficient, in many cases, to judge the technical feasibility of satisfying a particular operational requirement. In other and more complex instances, special feasibility studies may need to be launched, often with the help of industry. In either event, final responsibility for a feasibility study rests with a single official in the Supply Department. He is assisted by a team or teams of experts in particular fields but his own task calls for high all-round technical and managerial ability, and the selection of suitable officers for such posts is of the greatest importance.

198. Where a feasibility study is carried out within a Government establishment, it clearly cannot normally be competitive. In certain circumstances, however, it might be both possible and desirable to engage two separate teams to undertake the work; the cross-criticism which is likely to arise during the subsequent assessment of the two studies will improve the value of the whole exercise. In cases where industrial experience is desirable at this stage, we recommend that two or more firms should be invited to compete in feasibility studies. Normally such studies will be of limited duration, and in such instances firms should be expected to undertake them without payment. In exceptional cases they may turn out to be prolonged and, if this is so, it would be both necessary and reasonable that an appropriate payment should be made. Firms would have the added incentive that they could hope, if they provided the most promising answer, to be invited to undertake further work on a paid basis. We recognise, of course, that, in view of the recent reorganisation of the aircraft industry, projects relating to aircraft and, in large part, to guided missiles, can today be put for consideration to only two competing consortia.

199. Whichever way they are carried out, feasibility studies should be limited to studies of the technical problems involved in satisfying an operational requirement. Normally, if only because of the need to save time, they do not involve any experimental work or engineering; but they do include approximate indications of the cost and time needed to complete the project. The Supply Department concerned, in co-operation, where necessary, with the operational staffs of the Service Departments, then decides which of the feasibility studies gave promise of the best answer, and whether to recommend a further step in developing the particular project concerned.

PROJECT STUDIES

200. In our view the next stage is the most important in the whole process of defining and satisfying an operational need, and is one to which inadequate attention had been paid in the past. What the new procedure is designed to achieve, from the point of view of central and interdepartmental control, is a careful study of the implications of the proposed weapon system, prolonged over whatever time is appropriate to the cir-

cumstances and aimed to provide, so far as possible, reliable answers to the following questions :—

(i) What are the scientific and technical problems that need to be resolved in perfecting every aspect of the weapon system concerned, taking into account the operational circumstances for which the system is designed?

(ii) In what particular fields is scientific and engineering knowledge insufficient to satisfy the technical and operational needs of the system, and what likelihood is there that the gaps in knowledge can be filled within an agreed time-scale?

(iii) If the industrial facilities and experience required to bring the project to fulfilment are not available, how readily can they be provided?

(iv) What is the likely cost of the research and development necessary for each stage of the project, in terms of money, categories of professional manpower, and time?

(v) What is the likely cost of production of the finished weapon system? And how certain are the estimated costs? Is there any industrial experience in the techniques involved, or is a long training period unavoidable?

(vi) What is the likely market for the finished weapon system both within our own Services and abroad? How long an operational life is the system likely to enjoy?

(vii) When re-examined in the light of the answers to the preceding questions, how valid does the original operational requirement appear, particularly when account is taken of the fact that the end-product may not become available for between five and ten years—a period in which the enemy's technological capacity, as well as his offensive and defensive capabilities, will also be increasing?

(viii) Would the completion of the research and development, and the production of the weapon system concerned, have any useful effect upon civil industry?

(ix) Can the commitment be filled with advantage through purchase from abroad?

If we are to continue to guard against the mistakes of the past it seems to us essential that once a feasibility study has been completed, and before a contract is let to industry for the development of a weapon system, answers to questions such as these should be systematically sought in a project study. Above all, it is essential that the cost of research, development and likely production should be looked at as a whole. In view of the years which intervene between the conception of a new weapon system and its completion, this entails fitting each project into the framework of long-term plans for defence expenditure.

201. Before the question of any such detailed project study would arise, the earlier process of defining an operational requirement and its technical specification will usually have entailed very little expenditure additional to what is catered for in the overheads of Government and industrial laboratories. A detailed project study would, however, be a specific undertaking,

and one which would cost an amount of money that would clearly vary with the technical difficulty of the project and with its ultimate military and strategic importance and cost. For example, there have been projects in the past whose ultimate cost and time-scale for completion have turned out to be many times the original estimate. Some of these projects were clearly going to be costly and, moreover, it was quite likely that they would develop in such a way that the final cost would greatly exceed the original estimates. Many factors no doubt influenced the course of individual projects, but it seems to us that they might have had a better history if a substantial sum had been spent at the start to provide a closer examination of their technical feasibility, timeliness and ultimate cost. Indeed, if our recommendations are to be satisfactorily implemented, it is essential that during the project-study stage, money should be spent at the same rate as if the project study had been, in fact, the first stage of a development contract. Thus, if the project is ultimately pursued to completion, no time will have been lost. If, on the other hand, it is abandoned as a result of the project-study report, the Government will have the necessary information for a final decision earlier than has sometimes been the case in the past, and it will have paid a relatively modest price for avoiding the substantial waste of money involved in abortive development.

202. We recommend that project studies of the kind we advocate should be carried out for all major projects before a development contract is placed.

THE PLACING OF A PROJECT-STUDY CONTRACT

203. It is for the Supply Department concerned to decide whether a project study should be placed with industry by means of a contract, or made the responsibility of a Government establishment. In either event, we recommend that a project study should be placed with only one group. If an extra-mural project-study contract is to be placed, it will be necessary to take into account the merits of the answers submitted to the preceding feasibility study and the known competence of the industrial undertakings concerned but, where practicable, suitable contractors should be invited to submit competitive proposals for a project study.

204. The scope of the project study should be agreed between the industrial undertaking selected for the task and the Supply Department concerned, and should be as specific as technical considerations allow. Arrangements should be made to permit close contact between those responsible for carrying out the study and the potential user. A single individual, assisted by a small steering committee set up by the Supply Department primarily concerned, should be made generally responsible for controlling the project study on behalf of the Government.

205. Once the decision to go ahead with a project study has been taken, a specific period should be estimated for its completion at an agreed price and, once the contract has been let, the work should normally be allowed to proceed to a conclusion.

206. A year's work at a cost of as much as 5 per cent of the total estimated research and development cost would not be inappropriate for an important defence project study.

THE TRANSITION FROM A PROJECT-STUDY CONTRACT TO A DEVELOPMENT CONTRACT

207. The dividing lines between what we have called a feasibility study, a project-study contract, and a development contract had previously been blurred. The mistakes of the past have often been due to the fact that major projects were embarked upon before it was possible to make adequate estimates of costs, time or technical feasibility.

208. Under the procedure that we advocate the transition from a project-study contract to a development contract would represent a critical stage of decision. The report on the project study, which would be the responsibility of the research and development authority, would provide answers to all or most of the general questions outlined in paragraph 200 above. It should then be possible for the Department concerned and the Defence Research Policy Committee (D.R.P.C.)—to whose role we refer in detail later—to take a reasoned and objective view, within the time-scale envisaged, of the technical feasibility of the project in the light of the amount of new scientific and engineering knowledge which it would require. On the completion of a project study it would also be possible for the D.R.P.C. to consider the general question of duplication of needs between the Services (a point to which we return in the next Chapter) and, if needs be, to draw the attention of the Chiefs of Staff to any such duplication. Correspondingly, the Chiefs of Staff, as advised by the D.R.P.C., would be better informed than they would otherwise be to decide whether the time-scale within which a given weapon system was likely to be completed was appropriate to projected strategic needs.

209. A project-study report would also provide the supply and user Departments, the Ministry of Defence and the Treasury with information about the demands which a new weapon system would make on available national resources ; about the costs and extent of deployment of the finished article ; about the technical and business adequacy of the groups with which it is recommended the contract should be placed ; about the possibilities of overseas sales ; as well as about the likelihood that the particular piece of defence research involved would assist in the development of civil industry. This report, combined with other relevant information, would form the basis for a final examination of the desirability of proceeding from a project study to a development contract.

210. We recognise that it may sometimes be necessary to place a development contract, either for the whole or part of a new weapon system, with a firm which at first sight appears less efficient than a competitor. Where considerations of this kind arise, it seems to us important to know the price of qualifying a technical judgment on such grounds. This cost can only be estimated by the Supply Department after a careful and critical project study of the kind we have proposed has been carried out.

211. We cannot over-emphasize the importance we attach to this stage of the procedure of transforming an operational requirement into a development contract. We believe that, if project studies of the kind we recommend had been regularly employed during the past fifteen years, and if the reports of these studies had been carefully assessed, both by the Departments con-

cerned and by the D.R.P.C., the country might well have had better value for money spent. For a common fault in the past has been to allow projects to drift from one stage to another without strict control at critical points.

Holding Contracts

212. In the course of a project study it will usually soon become apparent whether it is likely to be successful. But in some cases consideration of a project-study report would take time, and it may be important to ensure that the teams which have been built up in industry to study the project are not left idle or, worse still, disbanded because of the time-lag between the completion of the project study and the letting of a development contract. We therefore recommend that, in order to maintain the momentum of promising projects, Supply Departments should have discretion to let a holding contract to bridge the gap. In our view it should never be necessary to let more than one holding contract for each project, and the contract should not run for more than three months. If the project-study report has been properly prepared, the Government should be able to reach a decision on it within this period. If at the end of a project study it is clear that no decision about proceeding further could be reached within a period of three months, we suggest that the Government should not take any steps to avoid the disbandment of the industrial teams responsible for the study.

Control of Development Contracts

213. Once a development contract has been placed, its management should become the responsibility of the originating Department (the Ministry of Aviation, the Admiralty, or the War Office).

214. We note with approval that in 1959 the Ministry of Aviation set up four Study Groups to consider

(i) project cost-estimating ;

(ii) the procedure for accepting operational requirements ;

(iii) the use of incentive contracts ;

(iv) the efficiency of the "limitation-of-liability" clause in research and development contracts ;

and that, on the basis of the reports of those Study Groups, the Ministry has not only clarified certain areas of responsibility but also improved certain procedures. It is also introducing new measures of cost-estimating in the work carried out within its own establishments. Cost control is accorded equal importance with technical control, and steps have accordingly been taken to bring the technical and administrative branches of the Department closer together. At the same time, contractors who make proposals for development projects are being asked to submit detailed cost programmes under the authority of a senior member of the firm and, wherever possible, they are being asked to bear the financial liability for the accuracy of their estimates and for the efficient management of the projects they undertake. Under these new arrangements, the responsibilty of the technical branches of Supply Departments can be defined as the assessment of the implications, in terms of scientific and technical effort, time and money, of each project undertaken

by the Department. One of the responsibilities of the Administrative and Contracts Branches, who alone authorise financial commitments on behalf of the Department, is to satisfy themselves that the estimates put forward by the technical staff, who must be fully provided with necessary advice from all required quarters, are valid.

215. The Ministry of Aviation is also attempting to improve the contractual arrangements it makes with industry by the greater use of incentive contracts rather than those based on cost plus profit allowance.

216. We understand that the War Office has benefited from the experiences of the Ministry of Aviation insofar as they have taken over procedures in use in those areas of research and development, responsibility for which was transferred to the War Office when the Ministry of Aviation was formed. Consultations between the Admiralty and Ministry of Aviation have also taken place.

217. Certain other new procedures, whose general aim is to improve the efficiency of research and development, are included in the following further recommendations which we wish to make. Some of these have already been put into effect or are being considered by the Ministry of Aviation, the Admiralty and the War Office.

(i) A development contract should be a specific contract to meet a specific requirement on lines indicated by a preceding project study. It should include clear-cut arrangements about costs, a time-scale for the various phases, and a list of the major technical problems assembled in order of priority. These should be checked, as the work proceeds, by the responsible technical official in the Supply Department. Any major variation which would affect the concept, cost or timing of the project should be referred back for consideration to the level at which the original decision of the project-study report was taken, and to the D.R.P.C. if this body was initially involved or if subsequent developments justify reference to that Committee.

(ii) If changes are introduced into the development of such magnitude as to necessitate the project being referred back to the D.R.P.C., that body should, if necessary, refer the whole project back to the Chiefs of Staff and the Minister of Defence.

(iii) As far as is technically and economically justifiable, the practice should be extended of making a single prime contractor responsible for the development of a complete project, subject to agreements with the Supply Department on the placing of sub-contracts.

(iv) The oversight of a development contract should, so far as the Government is concerned, be the responsibility of a single technical official in the Supply Department. Where necessary, he should be the Chairman of a team or management board on which should be represented the technical, financial, and contracts divisions of the Supply Department concerned, as well as the potential user and a representative of the prime contractor. Officials of relevant Government research establishments should also be brought into this monitoring process.

218. In general, we wish to emphasize that an essential pre-requisite for the successful guidance of a development project is the scientific and technical competence of the staff of the originating Department, together with their experience of industrial methods. Without this, no amount of good administration can assure the orderly progress of a development contract. The longer a project is delayed in its development, the more it costs and, if carried to completion, the shorter the life of the finished product. Equally important is the fact that poor costing and technical estimating at the start might lead to the selection of an apparently superior project which is not only doomed to failure but also eliminates from consideration a less ambitious and less costly but nonetheless more feasible project. Only careful project studies carried out in advance could be expected to reduce the frequency of this happening.

219. Co-ordination within Departments is also important. We have been informed that lack of it has led to delays and difficulties. These can be obviated only if there is proper co-ordination between Directorates which overlap in technical fields.

The Break-Clause

220. Finally, in view of the comments we have heard expressed about the unsettling effect on industrial contractors of the " break-clause "* in defence contracts, we think we should comment briefly on this topic. We have already indicated that the resources which are available for defence research and development are completely stretched. Adding a major item to the list of projects in progress may alter the balance completely, in the same way as the balance can be seriously affected by eliminating a single big contract. Correspondingly, the general pattern of the programme may be affected by some major change in national policy determined by political or economic considerations, either at home or abroad. This is one of the reasons why the whole programme needs to be kept under review so as to determine what consequential changes are called for as a result of the introduction or elimination of some major item of work, or because of a change in general national policy. Another derives from the fact that the U.S.A. and the U.S.S.R. are able to devote enormously greater resources to defence technology than we do and that, consequently, our own projects will be rendered obsolescent, from time to time, by developments in these two countries. These considerations provide the only justification, but a sufficient one, for the retention of a " break-clause " in defence contracts, whether for development or production, placed with industry. The feasibility and project studies described above should go far to prevent the need for operating it for any further reason.

* The " break-clause " is a standard feature in defence contracts. It enables the Supply Department to terminate the contract after a period of notice (generally three months) specified in the contract, subject to a claim by the contractor for compensation under the contract for certain losses resulting from the termination.

CHAPTER VIII

THE ROLE OF THE D.R.P.C. AND GENERAL CONCLUSIONS

221. This Chapter is devoted mainly to an examination of the composition and working of the Defence Research Policy Committee (D.R.P.C.) and its Staff. But by way of introduction we wish to refer first to one of the most important problems which it is the task of the Ministry of Defence and the D.R.P.C. to resolve. We refer to the avoidance of unnecessary duplication in defence research and development requirements and programmes, whether it be national duplication within or between our own Services, or international duplication between ourselves and our allies.

NATIONAL DUPLICATION

222. No machinery can prevent the duplication that arises from a desire to avoid risking dependence on a single approach to a problem, or on a single contractor. How far bets should be hedged must be a matter of judgment, usually on the part of the responsible Controller in the Supply Department. Some duplication is obviously justifiable where a project entails a technical advance into new fields. Hindsight suggests, however, that, although it has sometimes proved fortunate that reliance was not placed on one approach, on the whole it would have paid to concentrate on fewer possible solutions, and to go in for greater and speedier industrial rationalisation.

223. The prevention of duplication between the Services, on the other hand, is a matter for interdepartmental machinery. This machinery, in the shape of the D.R.P.C., exists and functions. In some important cases, it has operated to prevent duplication: in cases where it has allowed apparent duplication it has done so advisedly, on the grounds that the operational penalty of forcing the Services to accept equipment which falls short of what they want would be too severe. This is not to say, of course, that its judgments were invariably right; but if, as we understand, all projects for development require its sanction, it cannot be said to lack the opportunity of forming a judgment.

224. We have two suggestions to make. First, we think that the effort to harmonise the needs of the different Services should more often start before the formulation of the operational requirement. Secondly, we believe that, as the cost of development is now so immense, every effort should be made to reconcile operational requirements so that a single design can satisfy more than one Service, thereby leaving more money for production. But if unnecessary duplication is to be avoided, then the Ministry of Defence will be required to exercise to the full the powers vested in the Minister of Defence, to which we referred in paragraph 170 of Chapter VI.

INTERNATIONAL DUPLICATION

225. Duplication in the development of weapon systems has occurred not only nationally, but also internationally between ourselves and our allies. Once more, it seems to be the case that it occurs because of conflicting policies and decisions taken at a higher level, rather than because workers in defence research laboratories are unaware of what is being done by their counterparts in allied countries. There is all manner of scientific and technical collaboration between ourselves, Commonwealth countries and other allies.

226. It is always necessary to bear in mind, however, that the resources devoted to the development of new weapon systems by the U.S.A. are as far in excess of our own as are the Russian. On the basis of published figures the disparity is all but tenfold. We cannot therefore hope to compete with the two giants on the international scene except in selected sectors of defence research. For that reason, we welcome a recent direction given by the Ministry of Defence that, in considering future development, the fullest possible information should be provided about comparable equipments that are under development or in service in other countries, in order to help in deciding whether we should embark on new ventures of our own or rely on overseas purchases. Information about overseas developments clearly needs to be taken into account when deciding whether to proceed from the stage of a project study to that of a development contract proper.

227. In particular, it is becoming increasingly necessary to eliminate wasteful duplication of effort among members of NATO and other countries of the Western world. Positive efforts, therefore, need to be made, in consultation with our allies, and particularly with the U.S.A., to prevent overlapping and to promote useful specialisation in defence research and development by different countries. Those countries which are well placed to take the lead in particular fields should do so with a view to supplying their allies' as well as their own needs. We know that a good deal of effort has already been devoted to finding a solution to this problem, but the results so far have been disappointing.

THE DEFENCE RESEARCH POLICY COMMITTEE

228. We have already referred to the important part the D.R.P.C. plays and should play in the control of defence research and development, particularly when the operational requirement is formulated, and at the stage when a project-study report is submitted. The Committee is an inter-departmental body the members of which are responsible for both the operational and scientific aspects of research and development in the Service Departments and the Ministry of Aviation. As already noted, it is chaired by the Chief Scientific Adviser to the Minister of Defence. Its meetings are also attended by representatives from the Treasury and the Ministry of Defence. As defined in 1947 the terms of reference of the D.R.P.C. were:—

> "To advise the Minister of Defence and the Chiefs of Staff on matters connected with the formulation of scientific policy in the defence field."

These have been redefined very recently and now read as follows:

"(a) To advise the Minister of Defence and the Chiefs of Staff on all scientific and technical matters which may affect the formulation and direction of defence policy.

"(b) To keep under review the defence research and development programme so as to ensure that it is appropriate to current defence policy having regard to available resources."

229. In addition to acting as a general advisory body on defence science, and as the body charged with the inter-Service co-ordination of requirements in orders of priority, the D.R.P.C. undertakes a broad annual review of the whole defence research and development programme. Unlike a capital investment programme, this is a standing list of uncompleted projects to which new projects are added as they are approved. Instead of allocating each project to a programme of "starts" for a particular year, the Committee attaches a priority to it and the Department concerned then times its start, subject to Treasury approval, according to its priority.

230. While the D.R.P.C. considers, as they arise, new individual projects which will make substantial claims on resources, or which imply important or controversial decisions of defence policy, it is the responsibility of the Supply Division of the appropriate Ministry to decide whether a project falls within this definition. It is, however, always open to the Ministry of Defence, the Service Departments or the Treasury to ask that any project should be considered by the Committee. In fact, about three-quarters of the total extra-mural expenditure on research and development relates to projects which have been approved by the D.R.P.C. itself.

The Defence Research Policy Staff

231. The Defence Research Policy Staff (D.R.P. Staff) is made up of four full-time senior officers (one from each of the three Services and a scientist of equal rank from the Ministry of Aviation) and eight part-time members. Seven of the part-time members are civilian scientists with executive duties in their parent Department, and they can bring to the D.R.P. Staff up-to-date knowledge from their Departments. The eighth is an administrative Civil Servant in the Ministry of Defence. The four full-time members of the D.R.P. Staff serve for a term which is not less than two and usually not more than three years. Previously a full-time scientist from the Ministry of Defence acted as Chairman of the Staff, but for various reasons this arrangement was changed about two years ago. At present he is chosen from the four full-time members and the intention has been to alternate the duty between the full-time members. The Service members of the full-time Staff also act as "Service advisers" to the Chief Scientific Adviser in the Ministry of Defence. In varying degrees they also have executive responsibilities in their parent Departments.

232. The terms of reference of the D.R.P. Staff are "to carry out such work as the D.R.P. Committee may direct". In practice, their main functions are:—

(i) To keep abreast of defence research and development in the United Kingdom and abroad.

(ii) To examine all defence research and development projects submitted to them, and to accord them inter-Service priorities.

(iii) To ensure that the items listed in (ii) above continue to be valid in the light of changing defence policy.

(iv) To initiate papers which the Staff think should be discussed by the Committee.

(v) To provide an informal link whereby the Ministry of Defence is kept informed of ideas for new weapons or equipment at an early stage in their emergence in a Service Department.

THE ROLE OF THE D.R.P.C.

233. Our evidence strongly suggests that, whatever the D.R.P.C.'s responsibilities may be on paper, it has so far not been able to play the full part expected of it in impressing its views on scientific matters upon the Committee of the Chiefs of Staff and in ensuring that the research and development programme as a whole is in balance and of the right size.

234. If the material for its annual review is to be properly presented, we believe its staff needs strengthening. We have not studied in detail the arrangements for drawing up the programme as described generally in paragraph 229. But we suggest that these should be reviewed by those directly responsible to see whether it is possible still further to improve arrangements for indicating the timing and incidence of costs, and so to facilitate the annual review.

235. As for individual projects, we think it important that there should be no exceptions to the rule requiring reference to the D.R.P.C. or its Staff of all staff targets, operational requirements, feasibility studies and project studies, however small the probable cost of the project. We also believe that rather more precision is desirable about which projects should come before the Committee, instead of being dealt with on their behalf by their Staff. We recommend that the criterion for submission of a project to the Committee itself should be that its development is expected to cost £250,000 or more, or that it has important repercussions on defence policy.

236. We accept that the Service officers on the D.R.P. Staff must inevitably regard themselves as to some extent advocates of their parent Services. Indeed, we think it is right that they should regard themselves as channels by which the Services and, in particular, the Chiefs of Staff can ensure that their views are fully understood and given due emphasis by the D.R.P.C. On the other hand, to prevent over-emphasis by any one Service of its particular needs and to achieve a better balance between the many factors, scientific, operational and economic, which need to be taken into account when determining the research and development programme, we recommend that the non-Service element in the full-time Staff of the D.R.P.C. should be strengthened. We suggest that this additional staff should consist of members of the Scientific Civil Service appointed to the Ministry of Defence from the Supply Departments concerned. We also think that it should include a full-time adminstrative civil servant. We further strongly

recommend that the Chairman of the D.R.P. Staff should be on the staff of the Ministry of Defence and should be made a member of the D.R.P.C. itself.

General Conclusions on Defence Research

237. The main theme of this section of our report has been our emphasis on the value of distinguishing clearly, in the case of major defence projects, the various stages which lead to the placing of a development contract, i.e. staff targets, operational requirements, feasibility studies, project studies and, finally development contracts. Decisions to proceed from one step to the next should be based on all available information about likely technical progress, cost and time scales. Since the full development contract is the really expensive stage in terms of committed resources, it is essential that it should be preceded by a proper study contract, the curtailment of which could prove a very false economy.

238. We would also emphasise that each of the authorities concerned with the project as a whole must know and accept the nature of its responsibilities at each stage. For major projects these are broadly as follows:—

(*a*) The Service Departments have the prime responsibility for formulating staff targets and operational requirements.

(*b*) The research and development authority (whether the Ministry of Aviation or a part of a Service Department) has the responsibility for formulating, conducting or supervising, and assisting feasibility and project studies, and for placing and controlling development contracts.

(*c*) The D.R.P.C. has the responsibility for advising the Minister of Defence and Chiefs of Staff on all scientific and technical matters which may affect the formulation and direction of defence policy, and for keeping under review the defence research and development programme so as to ensure that it is appropriate to current defence policy, having regard to available resources. In the discharge of these terms of reference the committee reviews staff targets and operational requirements in the light of their ultimate impact on defence research and development, and sponsors, subject to Treasury approval, feasibility studies, project studies and development contracts.

239. If all the procedures which we have proposed are adopted, we believe that they will yield as great a measure of certainty as can be secured in a very uncertain field. There will, however, be times when the development of a project either turns out to be much more expensive than had been expected, or takes so long that the requirement for which it was intended will have vanished before the equipment is ready. The measures we have proposed are designed to detect cases of this kind at an early stage. But we shall not achieve the best results unless the Government is also prepared to cut its losses and cancel projects even when a great deal of time, money and effort has been devoted to them. In these cases it is always tempting—because cancellations may be thought to argue incompetence—to go on in the hope that the effort already spent will in the end not be wasted. But the truth is that, however much money and effort may have been spent on a project, it is not worth spending more unless the development when finished will meet a real need in an effective way.

240. Nowhere is the saying "circumstances alter cases" more true than in the field of defence research and development. We cannot, therefore, hope that the additional measures which we have proposed for its control will necessarily achieve the maximum increase in efficiency that is theoretically possible. In the end, the quality of the country's effort in defence research and development depends upon the scientific and engineering genius and administrative skill of the men who are engaged in this field of work, and on the judgment of defence research Directors and their opposite numbers in the Services. As is shown by the United States and the U.S.S.R. there is virtually no limit to the potential demand for defence research and development. Its volume can, indeed, be decided, it seems to us, only as some arbitrary proportion of the total national resources which can be devoted to defence. The problem of deciding which of many possible projects to foster is, in the circumstances, extremely difficult, and we can only repeat that decisions in this field ultimately depend on the skill of the Services in formulating their operational requirements, on the scientific and technological competence of those whose responsibility it is to advise how the requirements are to be met, and on their experience of industry. We are confident, however, that, granted first-rate personnel, our recommendations can lead to a substantial improvement in both efficiency and economy.

Organisation
and
Staff Management

CHAPTER IX

ORGANISATION

THE SIZE AND LOCATION OF RESEARCH ESTABLISHMENTS

241. The research establishments or units wholly financed by Government vary greatly in size. Expressed in terms of the number of staff in the Scientific Officer Class (or analagous grades) they range from two to three research workers in some of the smaller units of the Medical Research Council to several hundreds in large establishments such as the Royal Aircraft Establishment of the Ministry of Aviation. Appendix IV gives details of these variations; it may be noted here that the following proportions of the Scientific Officer staff are in establishments with fewer than 30 research workers: M.R.C. 75 per cent.; A.R.C. 54 per cent.; D.S.I.R. 15 per cent.; and in the three Defence Departments 8 per cent.

242. Broadly speaking, establishments are usually large in defence, where they are concerned mainly with applied research (with future development very much in mind), or with development work itself. A few very small defence research units also exist, either associated with the larger establishments or geographically isolated for specific purposes such as weapon testing. Most of the stations of D.S.I.R. are also relatively large, and they too are engaged predominantly on applied research. On the other hand, while the A.R.C. and M.R.C. administer a few large research establishments (such as Rothamsted Experimental Station and the National Institute for Medical Research), most of their units are small ones, and they are generally attached either to universities or to hospitals. All these small units are concerned with highly specialized subjects, many having originally been built round the work of some outstanding research worker.

243. The A.R.C. differs from the M.R.C. in having a number of medium-sized and small self-contained institutes—there are 24 with fewer than 30 Scientific Officer Class staff—scattered throughout the country, often geographically isolated from other research establishments. There are also six comparatively small and similarly-isolated D.S.I.R. stations. Many of these medium-sized and small establishments cover a number of scientific disciplines.

244. There is a serious danger that the geographical isolation of small research establishments, in which one may find as few as one or two research workers in any particular discipline, may lead to intellectual stagnation and to a general deterioration of the standard of work done. This is especially so if, as is often the case, staff spend the greater part of their potentially creative years in such establishments.

245. Small establishments also provide far less opportunity for removing staff from one field of research to another either as changes occur in the programme of work, or to prevent individuals from getting into a rut. Any attempt to achieve this by moving staff from one establishment to another is usually difficult to arrange because of domestic reasons, particularly as between widely separated laboratories.

246. As we have already said, opportunities for frequent personal contact between research workers in related and also in unrelated fields are very important to the health of a research establishment. There are three obvious ways whereby the Research Councils and Government Departments can help to foster such contacts. The first is by creating large multi-discipline research establishments such as Rothamsted, with at least half a dozen research workers in each of a number of specialised fields; second, by locating establishments close to each other or, better still, on the same "campus", as has been done, for example, at Porton, where a Microbiological Institute has been sited close to another which uses related techniques; and third, by attaching small units, where this is possible, to universities, as is now the practice in the M.R.C. and the A.R.C., or to colleges of technology. Such arrangements have the added advantage that technical services such as routine chemical analysis and statistics, as well as domestic facilities, can be shared, with a consequent reduction in overheads.

247. In 1943 the Barlow Committee drew attention to the need to site research establishments within easy reach of a university or close to other establishments working on kindred problems. No doubt many practical difficulties have prevented this from being done, particularly in the case of agricultural research establishments, but the fact remains that little attention appears to have been given to this issue in the intervening years. We recommend, therefore, that the Office of the Minister for Science should take on the responsibility of ensuring that this factor is given proper weight in the siting of new laboratories.

248. As to existing laboratories, there are a few, in particular some of the small stations and institutions in D.S.I.R. and in the A.R.C., which seem to us to be both too small and too isolated to inspire much hope in their continued success. We recommend, therefore, that the Research Councils and Government Departments should examine the possibility of amalgamating or grouping small isolated establishments.

Research Directors and the Formulation of Policy

249. As we have already described, the procedure in the A.E.A. and D.S.I.R., as well as in the other Research Councils, is that a central body, assisted either by general or specialist advisory boards or committees, determines the broad policy which governs the organisation's activities. While this kind of broad direction comes from the centre, new ideas and proposals for new lines of research, as well as the formulation of research programmes, depend very largely on the Directors and staff of the research establishments themselves. Because of their knowledge and experience, Directors occupy a key position in this respect.

250. This must be, or should be, true whatever the nature of the organisation. But the formal association of Directors with the central bodies which determine policy differs greatly between the A.E.A. and the other research institutions. In the A.E.A. the importance of the Directors and Managing Directors is recognised by their representation on the central Executive Committee of the Authority as well as on the main committee which advises the Authority on research—the Research Policy Committee. Furthermore, the Member for Reactors, the Member for Production and Engineering, the Member for Weapons Research and Development, as well as the Member for Finance and Administration, are members of the Authority and also have direct executive responsibility for their respective fields of activity. The position is completely different in the case of the Research Councils. Apart from the Secretary of the Council, who is, of course, executive head of the Department, no member of the D.S.I.R. scientific staff sits either on the Council for Scientific and Industrial Research, or on those of its main committees which are concerned with policy. This is also true of the A.R.C., the M.R.C. and the Nature Conservancy.

251. There is a possible weakness here. It stands to reason that the more successful a Research Council is in recruiting to its staff the best talent there is in its field, the more likely it will be that the staff becomes more informed about the activities and purposes of the organisation than the men who have the statutory and public duty of looking after its affairs. We therefore recommend that some means should be devised whereby the Directors of at least the larger establishments could become effective participants in the meetings of the Research Councils and their main policy Committees. (In D.S.I.R. and A.R.C., where there are several large establishments, there would no doubt have to be a rota system). Such arrangements would not only be of value to the Councils, because of the Directors' knowledge and experience, but would also be of value to the Directors, whose influence would be improved in a variety of ways. Similar arrangements would be of value in certain Government Departments, in particular in defence, where we think that some of the Directors of research establishments should be brought into more formal association with Headquarters bodies concerned with the formulation of departmental policy on research and development. We have already referred to this question in paragraph 194 of Chapter VII.

Advisory Bodies to Research Establishments

252. We have also referred to the various ways Directors of Government research establishments are helped in the management of their programmes. In summary they are as follows:—

(*a*) The Director may be advised by a Board or Committee, of which he is a member. Such bodies, which normally include user representatives, are not concerned with the day-today running of the establishment, but give general advice on the programme as a whole. This is the usual practice in D.S.I.R. The Council has also recently set up, as an experiment, small Steering Committees for some of its stations,

to which the Director is responsible, and of which he is a member; these act as an executive arm of the Council.

(b) Alternatively, the Director of an establishment reports directly to the Headquarters of his organisation, which in turn seeks advice on the work of its units or establishments from standing specialist boards or advisory committees. These advisory bodies are usually concerned with the work carried out in more than one research establishment, and include representatives of industry and the universities. They are illustrated by the A.R.C. Standing and Technical Committees, and by such advisory bodies to the Ministry of Aviation as the Aeronautical Research Council and the recently-formed Electronics Research Council.

(c) In a third category, as in the case of the small units of the M.R.C. and A.R.C., a Director will be responsible directly to the Headquarters of his organisation, which may appoint consultants to assist him; this is the rule in most Admiralty research establishments.

253. The A.R.C. also relies on *ad hoc* Visiting Groups to review the programmes of their units and establishments every five years or so (see also paragraph 104 of Chapter III and paragraph 142 of Chapter V). These Visiting Groups, which are appointed by and report to the Council, consist of a Chairman, who is generally a member of the Council, three or four specialists (usually of professorial status), and someone with practical farming experience. They are accompanied during their visits by members of the Headquarters scientific and administrative staffs. We understand that such groups are concerned not only with the intrinsic scientific merits of the work in relation to the station's programme, but also with general organisational questions, including an assessment of the value of the work done by individual members of the staff.

254. We wish to repeat that we regard these Visiting Groups as a most valuable institution. Directors of research establishments whose work is of value to users outside Government should clearly be able to consult advisory groups containing representatives of the main users. Scientists from universities and colleges of technology who are expert in the disciplines or subjects covered by the establishment are also of great value on these advisory bodies. To maintain their effectiveness the membership of such advisory bodies should not be allowed to become too static. On the other hand, we do not think that a Steering Committee on the lines being tried out by D.S.I.R. should be a normal feature in the running of a research establishment, although it may be useful as a transitional measure in certain circumstances.

255. Where a research establishment is controlled by a Government Department which is also the main user, as in defence research and development, advisory boards are also of value, not so much because they can represent user requirements, but because university or industrial representation ensures an independent and critical approach which can act as a stimulant to the work of the establishment concerned. Where the work of the establishment covers a relatively narrow field, a small advisory body of independent specialists in that field can also be of value. Another useful

device in the case of establishments whose work covers a range of disciplines is to appoint, as the Admiralty does, individual consultants for short periods to deal with specific aspects of the establishment's work. Since there are a number of research establishments, both in the civil and in the defence field, which do none of these things, we recommend that the Departments concerned should give serious consideration to the formation either of advisory bodies, or, as an alternative, to the appointment of independent specialists to act as consultants either on part or on the whole of an establishment's research programme.

256. Since we are particularly attracted by the A.R.C. system of *ad hoc* Visiting Groups as a means of obtaining an independent check every five years or so on the work of establishments, we also recommend that consideration be given to the extension of the use of such groups to other organisations in the civil field. We recognise that there may be security difficulties in the case of establishments engaged mainly on defence work.

Links with Academic Institutions

257. There are a number of ways in which links can be maintained between Government research establishments and the universities, e.g. through extra-mural contracts, the use of university consultants (both for short-term advice and also for work in Government laboratories during the long vacation), students' vacation schemes, and membership by university scientists of advisory committees. Still more can be done. We welcome, for example, the view of the University Grants Committee (Report for the Quinquennium 1952–1957; Cmnd. 534) that the universities should give serious consideration to the possible use of facilities for training in research outside the universities, in particular in the Research Councils. We also think that more should be done to enable university scientists to have access to special facilities available in Government research establishments in order to pursue enquiries of their own devising. This issue is to some extent bound up with the difficult problem of having non-academic laboratories recognised for the purpose of graduate and post-graduate work. Nonetheless, we recommend that those in charge of Government research organisations should consider with university authorities means whereby the two can achieve a closer liaison.

258. This recommendation also applies to the colleges of technology. A number of senior scientific civil servants are already members of the governing bodies of these colleges or act as part-time lecturers. We note that the arrangements for attaining Membership of the College of Technologists (the post-graduate award administered by the National Council for Technological Awards) specifically allows for a substantial part of a student's programme to be carried out in industry or at a Government research establishment. We therefore hope that establishments will co-operate in these arrangements both by supplying the necessary joint supervisors and by encouraging junior members of their own staff to work for the M.C.T.

259. We return in Chapter X to the question of the interchange of staff between Government research establishments and the universities and colleges of technology.

Links with Users

260. We referred in Chapter II to the formal arrangements whereby user requirements can be taken into account in the formulation of research and development programmes and in Chapters IV and VII we discussed this problem in relation to civil and defence projects. The following paragraphs are concerned with certain organisational issues which arise on the civil side.

261. In Chapter IV we discussed the particular problem confronting Government Departments which are not themselves responsible for research establishments, but whose affairs are greatly influenced by technological considerations. Several of these, such as the Ministries of Education, Housing and Local Government, and Transport, are responsible, directly or indirectly, for the expenditure of very large sums of public money on undertakings which are considerably affected by the results of research. If existing scientific knowledge and the new knowledge which further research can provide are to be brought to bear on the work of such Departments an effective relationship is essential between, for example, the Ministry of Transport and the Road Research Laboratory of D.S.I.R., the Ministry of Education and the Building Research Station of D.S.I.R., and the Ministry of Housing and Local Government and the various Government research organisations that cover subjects within its ambit, for example, the Water Pollution Research Laboratory (D.S.I.R.).

262. Some Government Departments without research establishments of their own but with a major interest in the results of research have appointed "Scientific Advisers", following on recommendations of the Advisory Council on Scientific Policy made in 1947.* This device has worked well at times but, from what we have gathered, it does not provide a complete solution to the problem. Where it has succeeded, it has done so because the Scientific Advisers or their staffs have been integrated with the administrative divisions of the Department in such a way that they are effectively used in the formulation of general policy and in the determination of the programmes of research of the organisations with which they may be directly or indirectly concerned. Unless this type of integration is assured, we do not think that many good scientists would find the job of Scientific Adviser attractive in certain Departments; they would have few staff and would have no direct responsibilities for research, and they would be uncomfortably placed between the main body of the Department and the research establishments of other organisations.

263. A supplementary method of strengthening the links between the scientist and the administrator which we favour is the formation of development groups. This is a technique of management which, as will be seen, has something in common with Operational Research and Organisation and Methods. The Ministry of Agriculture's experimental farms working in conjunction with the rest of the National Agricultural Advisory Service provide an example of a rather similar approach.

* First Annual Report of the Advisory Council on Scientific Policy (1947–48); Cmd. 7465, paragraph 10.

264. A short history of the development group on educational building set up in 1949 by the Ministry of Education, and a statement of the factors judged essential to its success, are given in Appendix V. Briefly, the Group is designed to bring scientific and technical knowledge to bear directly on the formation and efficient execution of building policy. It brings together at Headquarters some thirty people including administrative officers (representing the policy-makers), H.M. Inspectors (representing the teachers who will use the buildings) and all the partners—architects, quantity surveyors and engineers—concerned in the design of a building.

265. The Group keeps in continuous contact with research scientists at D.S.I.R. Stations and elsewhere ; it regularly investigates educational requirements in the light of any new developments in teaching techniques ; and it co-operates with manufacturers in evolving new building components or methods. It advises the Minister about appropriate standards and costs, and also about the form that his controls should take—standard plans have always been firmly opposed. By actually designing and erecting buildings, it demonstrates that these controls are reasonable and workable. And it gives guidance to local education authorities and others about ways to secure maximum value for money. Without the work of the Development Group the educational building programmes carried out since 1949 would, we are told, have cost some £300 million more than they have.

266. An essential feature of the Development Group is its central position in the administrative structure of the Department ; it is an integral part of the Branch responsible for capital investment programmes and for the approval of individual building projects. This Branch is itself under the joint control of an Assistant Secretary and the Chief Architect.

267. We understand that several other Government Departments have recently set up development groups to deal with similar problems of building. We welcome this move but wish to emphasize that such groups should be as strong on the administrative and " user " sides as on the technical side, and that the work on the group needs to be fully integrated with the general policy of the Department. Close and confident collaboration between the different partners in the team is essential. This approach cannot develop its full potential if administrative members think it their job to express an administrative as against a technical point of view, or if the technical members think of their requirements as in some sense in opposition to those of the representatives of the users. The various interests represented in a development group must be ready to understand and respect one another's special skills and experience.

268. We think it might also be worth while to explore applications of this technique outside fields where capital investment is involved. As we understand it, the essence of a development group is to bring together in one team the representatives of different and potentially conflicting interests for the close and continuous study of some executive activity (or range of activities) within the Department's field of interest. The group can thus assist the Department in formulating its controls or guidance in the way most likely to help the users and to secure the best value for money. The

activities which can best be studied in this way are typically those which involve finding the best possible compromise between a variety of administrative, financial, scientific, technical and user requirements and in which numerous users such as local authorities, industrial firms or the Department's own staff are engaged.

269. We recommend that Departments generally should consider whether the development group technique can be applied to certain aspects of their work.

CHAPTER X

PROBLEMS OF STAFF MANAGEMENT

270. The effective management of research establishments depends very largely on the way they are staffed. We were not surprised, therefore, that time after time during the course of our enquiries we found ourselves engaged in an examination of some aspect or other of the Scientific Civil Service.

271. With the exception of a relatively small number of staff with qualifications in engineering, geology, and the agricultural sciences, all those engaged on research and development in Government Departments, including D.S.I.R., are members of this Service. The scientific staff of the Agricultural Research Council and of the Nature Conservancy, while not members of the Service, are employed under corresponding conditions of service, including grading and salaries (but with different pension arrangements). The staff arrangements in the Atomic Energy Authority are also broadly comparable to, although somewhat more flexible than, those of the Scientific Civil Service. The Medical Research Council has its own conditions of service; salaries for non-clinical staff correspond in general with those paid to holders of comparable posts in the universities, and for clinical staff they correspond with those of comparable medical staff in the National Health Service.

The Scientific Civil Service

272. The Scientific Civil Service was established in its present form on the basis of a report of a Committee on Scientific Staff which was set up by the Treasury, towards the end of the last war, under the chairmanship of Sir Alan Barlow, to undertake a survey of the remuneration and conditions of service of scientists in Government Departments. In addition to changes proposed by this Committee, the Government, as described in the White Paper on the Scientific Civil Service published in 1945 (Cmd. 6679), introduced further important changes, including the formation, in addition to the Scientific Officer Class, of two separate categories of supporting scientific staff, the Experimental Officer Class and the Assistant (Scientific) Class. The central aim of all these changes was to provide " better conditions of service for scientists, and in particular conditions under which their own experimental research will be both facilitated and stimulated; improvement of their status and remuneration; and centralized recruitment ".

273. Both the Report of the Barlow Committee and the White Paper make it clear that one of the main concerns which led to the reorganisation of the Scientific Civil Service in 1945 was the need to ensure that Government research establishments would recruit a fair share of the best scientists coming from the universities during the post-war period of recon-

struction, when the market was likely to be highly competitive ; and further, that they would be able to retain a reasonable proportion of those who had entered the Service during the war years (when recruitment was on a temporary basis). It was essential to achieve these objectives if the general standing of Government research and of Government scientists was not to be allowed to fall to its pre-war level.

274. The Scientific Civil Service emerged from the 1945 reorganisation as a part of the traditional Civil Service, offering a career in research* to graduates and non-graduates with the same security and corresponding conditions of service (including, later, the same pension arrangements) as apply to other professional Classes and to the general Administrative, Executive and Clerical Classes of the Civil Service. There are, however, two important differences between the conditions of service in the Scientific Officer Class and in the other professional or general Classes of the Civil Service.

275. First, the White Paper of 1945 holds out firmer expectations of promotion for recruits to the Scientific Officer Class than apply generally in the Civil Service.

> "The Committee recommended that the outstanding scientist should have a reasonable expectation of reaching the Principal Scientific Officer grade in the early thirties and the Government agree that staff complements should be so arranged as to ensure this. Every Scientific Officer of proved ability should reach this grade in a reasonable period."

Second, a special merit promotion scheme (see Appendix VIII) was introduced in 1946 whereby the work of research workers of exceptional ability could be recognised by their promotion to senior posts outside normal departmental complements. A scheme of this kind does not apply in any other Class of the Civil Service.

276. On the other hand, while virtually all entrants to the Scientific Officer Class reach the Principal Scientific Officer grade, the prospects of still further promotion have turned out to be much poorer than are those of an Administrative Class Principal (a grade with the same salary scale as that of the P.S.O.). For every two P.S.O.s in the Scientific Officer Class there is only one officer in a higher grade ; in the Administrative Class the numbers in higher grades are almost the same as the number of Principals.

277. Details of the duties and recruitment arrangements, and of the grading and salary structure of the Scientific Civil Service are given in Appendices VI and VII.

278. In this part of our enquiry our attention has turned mainly to the problems of the Scientific Officer Class—there are about 3,400 staff in this Class in Government Departments, and about another 900 in the

* Although there are a number of Scientific Officer Class posts not directly concerned with research, the great majority of those recruited to the Scientific Civil Service can expect to be engaged in research and development or in its management for the whole of their career.

A.R.C.—as the members of this Class have the greatest influence on the quality and management of the work undertaken in Government research establishments. We fully appreciate, however, the important role played by supporting staff, of which there are about 7,000 in the Experimental Officer Class and about 6,400 in the Assistant (Scientific) Class (including in both cases the A.R.C.). Their numbers and quality suggest that the Civil Service has devoted considerable thought and effort to ensuring that the best use is made of scarcer staff with the highest scientific qualifications. Indeed, our impression is that the Civil Service is ahead of most other research organisations in this respect.

OBJECTIVES

279. The problems which are associated with the existence of the Scientific Officer Class in the Civil Service have, we think, tended to be confused too much by comparisons between the Scientific Officer Class and the Administrative Class. As a result, too little attention has been paid to the fact that, from the point of view of staffing, there will always be important differences between scientists engaged in research and development and administrators who deal with the more general affairs of a Government Department. One main difference is that, while a proportion of research scientists remain productive either in one or more specialised fields of research for the greater part of their careers, most scientists do their best research early in their careers. On the other hand, the quality of administration is something which is expected to improve with age and experience. A second main difference is that in most types of research, once a man has established himself, there is neither need nor justification for anything like the same measure of supervision or of reference upwards as is required in the Administrative Class. This second difference is reflected in the lower ratio of senior to junior posts in the Scientific Officer Class as compared with the Administrative Class.

280. But these seem to us to be differences which also mean that the intrinsic importance of the work done at an early age by research workers should be appropriately recognised in terms of pay and promotion; and that, in order to hold down the average age of research workers in general, and to provide adequate outlets for older men, deliberate provision should be made for transfers at appropriate stages either to other types of work or to other classes in the Civil Service, or to industry or education. This last point raises fundamental issues to which we return later in this Chapter.

281. These considerations must be constantly borne in mind by the Government in devising the methods which it uses to achieve its general staffing objectives for the Scientific Civil Service. These objectives still remain:—

(*a*) the recruitment and retention of sufficient staff of the necessary quality, including a reasonable proportion of those of exceptional ability; and

(*b*) the creation of conditions in which research staff can do their best work—this includes ensuring that the best use is made of those of

exceptional ability, offering a reasonable and stimulating career to the average man, and recognising at the earliest possible stage in their careers those who are unlikely to have further success as research workers.

282. Whatever may have been the merits of the recruitment arrangements and conditions of service of the Scientific Civil Service when it was formed some sixteen years ago, we doubt whether the present structure of the Service or the manner in which it has been administered enables these objectives to be attained.

283. The system introduced in 1945 has resulted in the following age and grade grouping:—

TABLE VI

Grade, salary and age structure of the Scientific Officer Class

(Grade and age structure based on information collected in 1958—see Note (¹) below)

Grade(²)	Current Salary £	Percentage of total	Lowest age (years)	Median age (years)
S.P.S.O. and above	2,650 to 7,000	20	33	49
P.S.O.	1,716—2,418	39	30	42
S.S.O.	1,342—1,654	29	25	32
S.O.	738—1,222	12	20	26

Notes (¹) Information for the whole of the Scientific Officer Class (including temporary staff) has not been compiled since 1958. The information presented above is however, consistent with that recently obtained by the Committee from a few Departments, including D.S.I.R., and broadly represents the structure of the Class as it is today.

(²) See Appendix VII for the full titles and salary details of all grades in the Scientific Officer Class.

This distribution is very different from that prevailing in the laboratories of industry, the universities and technical colleges, and the Medical Research Council. The principal defects which it reflects are that too many young scientists are committed prematurely to a permanent career in Government research and, second, that those in their forties and fifties have no option but to stay on as research workers (usually at Principal Scientific Officer level) long after they have made their main contribution to research, and in a period of their careers when their experience and ability would be of value if directed to other activities.

284. Another major criticism levelled at the administration of, and conditions of service in, the Scientific Officer Class by many of those with whom we discussed staffing arrangements was lack of mobility. According to our evidence, this reveals itself in two ways. First, there is insufficient movement of research staff between establishments or, indeed, from one line of research to another. As a result, Government scientists are deprived of the stimulus of new work, at the same time as they are denied the wider experience necessary for those who ultimately rise to higher positions of responsibility. Second, there appears to be an absence of any planned arrangements for exchange or secondment of research staff between Government research establishments on the one hand, and the universities or industry on the other, or even, indeed, with other branches of the Civil Service. Because of this, members of the Scientific Civil Service enjoy fewer opportunities than they should of broadening their experience in a way which would be beneficial both to themselves and to the Government.

285. We do not wish to give the impression that failure to deal with the problem of mobility of research scientists is restricted to the Civil Service. In varying degrees our criticisms apply also to the research departments of industry and to the universities. Industry is better placed, however, for dealing with the problem, since its research staff have outlets to other activities within their organisations, for example, design, production and sales; and in the universities there is always ample scope for increased teaching or administrative responsibilities.

286. While we conclude that too high a price has been paid—in terms of lack of mobility—in achieving some of the goals of the Government's post-war reform of the Scientific Civil Service, we are also aware that any departure from current practice, in an effort to remedy the situation, must take into account the fact that the competition for scientific manpower remains strong. Our recommendations in the remaining passages of this Chapter have this very much in mind. We recognise that changes can be introduced only gradually if the Government is to have a fair chance of recruiting the numbers and quality of scientific staff that it requires; that there is no single solution to the problem of mobility; and that only through a combination of measures will it be possible to achieve any important improvements. But, having said this, we are bound to add that the more we have learnt, the stronger has our impression grown that management at all levels has not faced up to some of the problems we have encountered, or, at least, has not exploited existing recruitment and management arrangements fully in order to improve the present situation. Some of the possibilities of improvement may be slender; but they need to be tried.

Premature Commitment

287. Consider first the problem we mentioned in paragraph 283; that the present system commits too many young men and women prematurely to a permanent career in a Government research laboratory.

288. We have wondered whether this could be changed by applying as a general rule the arrangements adopted by the Medical Research Council. The M.R.C. offers junior staff appointments in the form of short and medium term contracts, and accepts as permanent staff only those research workers, generally over the age of thirty, who have proved their research ability over a period of years. This system has many attractions. As a general measure, however, we do not think that it would meet the needs of a Service which covers a wide range of scientific activities and which, as a whole, does not yet enjoy the kind of prestige the M.R.C. does in the medical world. Some of the better-known Government research establishments could, none the less, help both themselves and the Scientific Civil Service as a whole if they were to make greater use of short-term and medium-term contracts to fill research posts now regarded as permanent. This practice might be extended as the competitive position of laboratories improves. We therefore recommend that the Treasury should discuss with Departments and staff representatives the possibility of giving Directors of certain research establishments greater powers than they have at present to recruit a proportion

of their staff on short-term or medium-term contracts at all levels up to and including the Principal Scientific Officer grade.

289. Apart from appointments to purely temporary posts the only other technique at present open to Government establishments wishing to reduce the possible numbers of premature permanent appointments is to offer Research Fellowships (see Appendix IX). These are available to outstanding research workers outside the Service, usually for projects of their own choosing within a field designated by the establishment. The Fellowships are given initially for a three-year period, but are renewable. These Fellowships are useful as far as they go, but very few of them are awarded, and they do not serve quite the purpose that we have in mind. We recommend, however, that a greater effort should be made to attract candidates for them and that the maximum value of the Fellowships, which at present stands at £1,220 per annum for a Junior Research Fellowship and £1,650 for a Senior, should be reviewed.

290. This general problem might also, we think, be eased to some extent by a more rigorous use of the probation period than seems to be the rule. Under existing regulations, all who enter the Service must normally serve two years' probation, which Departments can extend to a total of four if they require a further period in which to assess an individual's capabilities. The view of some of our witnesses—and we accept it—is that a number of recruits become established members of the Scientific Civil Service before their ability as research workers has been properly assessed. We recognise the difficulties of judging research ability within a probation period of two years. None the less, we recommend that all those concerned, including the immediate supervisor (and first reporting officer), should be reminded that it is in the interests not only of the Service but also of the probationer himself that anyone thought unlikely to have a reasonably successful career in a Government research laboratory should not be retained in the Scientific Civil Service.

291. Assessment of merit during the probation period is naturally easier where the individual concerned has already been employed in a temporary capacity while waiting for establishment through the Civil Service Commission competitions. A considerable proportion of Scientific Officers and Senior Scientific Officers in some laboratories have, in fact, been recruited in this way. We recommend that this practice, which also gives the individual concerned a better chance to decide whether he is likely to find satisfaction in a Civil Service career in research, should be extended.

Promotions to the Principal Scientific Officer grade

292. As the 1945 White Paper implies, almost all who join the Scientific Officer Class will eventually reach the Principal Scientific Officer grade. Generally speaking, and leaving aside older recruits and late developers, those who are above average ability can expect to reach the P.S.O. grade in their early thirties, the average in their mid-thirties, and the below-average in their forties. The proportion who fail to reach the P.S.O. grade is less than 5 per cent. Those who are successful as P.S.O.s. and who have managerial qualities as well as research ability will in due course be

promoted to the higher grades of the Class. Those of outstanding research ability may be promoted to non-managerial posts under the Special Merit Promotion Scheme, and are then free to concentrate on research.

293. It has been suggested to us that this so-called " automatic escalation " does not distinguish enough between the above-average and the mediocre research worker. The former may be promoted to the P.S.O. grade (starting salary about £1,700) before the latter, but after a few years have passed both will be receiving the maximum of the P.S.O. salary scale (slightly over £2,400). Such a system, whereby mediocre staff ultimately achieve the same rewards as do those who are above-average, fails, it is said, to provide proper incentives and may also result in a slackening of effort, particularly in the case of those who are promoted from the S.S.O. to the P.S.O. grade at well above the average age. Many of the latter will not expect further promotion, yet know that they will automatically rise by way of annual increments to a salary of about £2,400 a year. Furthermore, it is claimed that the present system deprives management of any means of providing an incentive to the average P.S.O. to make the effort to undertake, for example, a new line of research.

294. The two main counter-arguments to these views are first, that they do not place enough weight on the fact that most of those who enter the S.O. class do so through Open Competitions which demand a high academic standard or proof of research ability, and second, that the present situation must be accepted if the Civil Service is to recruit the staff it needs. Against this it can be claimed that the way to do justice to the above-average worker is to ensure his early promotion. But none of our witnesses was suggesting that over the Scientific Civil Service as a whole—as distinct from particular departments or research establishments—the above-average P.S.O. does not have a good chance of reaching S.P.S.O. or even higher grades. The real cause of the concern of those who criticise present arrangements, it seemed to us, was that insufficient use is made by some research organisations of accepted grading policy or the Special Merit Promotion Scheme in order to give their best people early and repeated encouragement.

295. These were not the only arguments put to us. Accepting the need for a career Service of much the present kind, a more radical change in the grading structure of the Scientific Officer Class has been suggested, both to ensure the adequate recognition of ability and to discourage the less effective from continuing in a research career beyond the salary level which would make it impracticable for them to transfer to other posts inside or outside the Service. The main feature of the proposal put to us was the division of the current P.S.O. grade into two parts (P.S.O. (2) and P.S.O. (1)), the former with a maximum salary half-way up the present P.S.O. scale, the latter with a maximum somewhat higher than the current P.S.O. maximum. Staff would have the same chances as now of reaching the P.S.O. (2) grade but only those whose ability was above average would be promoted to the new P.S.O. (1) grade.

296. Various objections to this suggestion have been made. First, it amounts to the introduction of an efficiency barrier and, as such a barrier is not found elsewhere at a comparable level in any other class of the Civil

Service, it is argued that it would be invidious and discouraging to introduce one into the major class of the Scientific Civil Service. Second, it is said to be contrary to all past experience to expect that such a barrier would be operated effectively by Departments. Third, the sub-division of the P.S.O. grade would add—we are told—to the present difficulties associated with the grading of scientific posts. And finally, it is held that a change of this kind, which would on paper reduce the career prospects of those who entered the Scientific Civil Service, might jeopardise recruitment.

297. Looking at the problems of the Scientific Civil Service as a whole, there is, in our view, considerable weight behind the objections to the reform of the present P.S.O. grade in the way suggested in paragraph 295. There is no doubt, however, that the problem of distinguishing adequately between the above-average and the mediocre research worker exists and needs further examination. As an interim measure, we recommend that steps should be taken by all those organisations whose staff are in the Scientific Civil Service, or who operate under similar conditions of service, to make greater use than in the past of existing procedures whereby the above-average research worker can be encouraged. We also recommend that Departments should review the standard of "proved ability" which they apply for promotion from S.S.O. to P.S.O., and that they should not promote anyone whom they are not fully satisfied will give satisfactory service in the P.S.O. grade (or, of course, in higher grades) for the rest of his career.

FLEXIBILITY IN GRADING

298. We have noted that some flexibility is accepted in the grading of certain scientific posts. The effect is that posts in the grades concerned can be upgraded in order to reward the incumbent for the quality of his work. This procedure recognises that in research the individual "makes the job" and that he should be able to influence the grading of the post he occupies in a way which does not apply to posts in other Classes of the Civil Service.

299. We think this is a good procedure. In principle, flexibility of this kind is recognised only up to the grade of Senior Scientific Officer, but we understand that something very like it applies in practice in certain Departments up to Principal Scientific Officer. We recommend that the principle should be recognised generally for all research posts up to and including the P.S.O. grade.

PUBLICITY FOR RECRUITMENT

300. A number of those with whom we discussed recruitment expressed concern at the ignorance of science undergraduates and of research workers in the universities and industry about the nature of the research undertaken in Government laboratories. We therefore examined the literature on the subject published by the Civil Service Commission, by individual Departments and by a few research establishments. It reveals a wide difference in quality and imaginativeness, and an apparent lack of co-operation between those concerned. We recognise that Directors of research establishments play a very important role in recruiting staff through their personal contacts with, in particular, the universities. None the less there is surely a need for some central co-ordination of both recruiting publicity and the arrangements for giving potential recruits experience of the work and working conditions

in Government establishments. We welcome, therefore, the recent formation by the Treasury of an interdepartmental panel to examine Civil Service methods of advertising and publicity for recruitment into the Scientific Civil Service.

MOVEMENT OF STAFF WITHIN THE SCIENTIFIC CIVIL SERVICE

301. A career in scientific research means specialisation. None the less, our impression is that neither the scientists nor the administrators responsible for the deployment of Government research staff have been sufficiently mindful of the danger of keeping the average research worker on the same kind of work and in the same surroundings for too long. Except for the " fliers ", whose creative capacity in their own fields never becomes impaired, we would stress the desirability of ensuring that young workers are given an opportunity and, indeed, are actively encouraged to change their line of research from time to time, even if this means a short period of retraining or moving from one research establishment to another. From the evidence given to us by Departments, movements of this kind are very infrequent, and much less so in the grades up to Principal Scientific Officer than in those above. Such moves, however, are certainly one way of helping to prevent research staff from getting into a rut.

302. We consider that moves of this kind, say, two or three times during the first ten to fifteen years of the career of the average research worker, would be particularly valuable both as a stimulant to the research worker himself and in providing, as part of a deliberate " training-for-management " policy, a body of mid-career staff with a rather broader outlook than they would otherwise have.

303. We appreciate that the frequency and timing of such moves must be determined by individual circumstances. In addition to the practical and personal difficulties in moving staff, particularly where a change of residence is involved, there are a number of factors which makes the problem specially difficult in the case of scientists. For example, research frequently requires a high degree of specialisation; and few young scientists will like being pushed from the job they are doing if the move carries the implication that they may not be as good as they imagine they are. Specialisation also creates a managerial problem. An organic chemist in one laboratory may not be capable of tackling, at least immediately, the problems in organic chemistry of another laboratory. There is thus a great temptation for a Director to recruit another specialist research worker rather than accept the period of adaptation required for existing staff to change their line of research.

304. Nevertheless, moves of this kind have been effected from time to time when circumstances have forced the issue. For example, changing defence requirements are responsible for a higher rate of movement between defence establishments than occurs on the civil side, and D.S.I.R., faced with the closing down of a laboratory, has recently carried out a transfer of staff, involving a considerable period of retraining, with substantial success.. But in our view what is wanted is a positive policy which is designed to ensure that the future effectiveness of individual research workers is not reduced, as it will be in most instances, if they are allowed to continue for too many years in one line of work.

305. It is inevitable that the interests of the individual may at times conflict with that of the research establishment. Accordingly, vitally important though it is to leave as much discretion as possible to research Directors, we think that Headquarters should exercise a greater degree of control in practice over movements of staff than they appear to do at present. In particular, exchanges between establishments, between establishments and Headquarters, and between Departments and other Government organisations, should be encouraged, and every assistance given to the individual in such moves, including, if desirable, a period of retraining (possibly outside the Service in particular instances). For this purpose, we recommend that the principal organisations concerned should work out accepted practices on this aspect of staff management and training, after discussion amongst themselves and with the Treasury, possibly through the medium of the Interdepartmental Scientific Panel.* We hope that particular attention will also be paid in this review to the arrangements for selecting staff for Headquarter posts; there would seem to us to be a serious failure at present to make the best use of the highly-qualified expert staff available.

MOVEMENT OF STAFF TO WORK OTHER THAN RESEARCH

306. Few members of any research institution will be doing active research at the bench throughout their lives. As people grow older, some naturally graduate to positions of management or to the direction of research teams; others develop a greater interest in the application of results and, if they are in industry, turn their interests towards design, production and sales, or personnel or general management. In universities, men may find a greater satisfaction in teaching. These moves take place from a variety of motives—from a desire for greater personal satisfaction than research may provide; from a wish to grapple with problems of policy; or simply from an urge for material promotion.

307. Opportunities for movements of this kind are reasonably plentiful in industry, the universities and colleges of technology, and salary differences make movement between industry on the one hand and the universities and colleges on the other, attractive at various levels. In contrast, transfers from the Scientific Officer Class to industry or to education have been few. Broadly speaking, the salary structure of the Scientific Officer Class, when compared with other civil occupations, makes such moves unattractive once a man has become a Principal Scientific Officer and is on a scale rising from about £1,700 to about £2,400. There have, however, been a few secondments of this kind, and we recommend that there should be more. But we realise that to facilitate permanent transfers on any significant scale would require a radical revision of the Scientific Civil Service which could result only from a more extensive enquiry than we have been able to make into the problem.

308. Meanwhile, there is much that can be done within the Civil Service itself. One range of openings for the more mature but less creative scientist exists in the dissemination of results of research and in advisory work

* The setting up of this Panel was recommended by the Barlow Committee and announced in the 1945 White Paper. Its members include leading scientists from Government Departments and administrative staff responsible for staffing matters. Its function is to keep under review the well-being and efficiency of the Government Scientific Service.

generally. As we said in Chapter V, too little importance has, in our view, been attached to this kind of work. It is work which demands first-rate qualities; a good scientific knowledge; a willingness to meet industrialists on their own ground; and higher than average ability in handling people.

309. The other main set of opportunities lies in management, either within a research establishment, at Headquarters or in the Administrative Civil Service. The Directors and senior staff of establishments, especially of the larger establishments, are, in the main, administrators, and as such have a good deal in common with their opposite numbers at Headquarters and in the Administrative Class. We should like to see these three groups of managerial staff more interchangeable. This has not been easy in the past, for the Administrative Class have known too little science and not many scientists have had much opportunity to become good administrators. On the whole, however, we think that careers in the Administrative Class are better planned now than in the Scientific Officer Class. We believe that with more carefully considered programmes of training and job rotation the administrative capacity of scientists can readily be improved. We also hope that as more and more of the better talent among the young people of the country opts for a scientific education, and as the national output of scientists and technologists rises, more of them will enter the Administrative Class of the Civil Service. But this is looking well into the future. We therefore wish to make two immediate recommendations.

(*a*) The development of a scientist as a good administrator is a matter of training and management. It may require his attendance at courses inside or outside the Service as well as experience in a variety of jobs. We recommend that all those responsible for the management of the Scientific Officer Class should review their present arrangements for training and job rotation within this Class.

(*b*) The Barlow Committee suggested that there should be more frequent transfers of scientific staff to the Administrative Class. The Royal Commission on the Civil Service (Cmd. 9613, published in 1955), while recognising the difficulties involved, also stressed the value of such transfers and suggested that the Service "should not lag behind outside practice in this matter". In fact, the number of such transfers has been negligible. We recommend that Departments concerned, in consultation with the Interdepartmental Scientific Panel, should consider whether, in addition to the secondments recommended in paragraph 120 of Chapter IV, more transfers could be arranged of research staff in or before their middle years to posts normally filled by members of other Civil Service Classes.

310. What we would hope to see is a much greater overlap between the Scientific and the Administrative (and indeed the Executive) Class of the Civil Service than now exists. We look forward to the day when men who began in the Scientific Civil Service will become Permanent Secretaries, and when others who started in the Administrative Class will occupy some of the senior posts in research organisations. We believe that there are jobs at present held by members of the Administrative Class which could be done as well by scientists, and *vice versa*—there are some that could, perhaps,

be done better. There should be much greater flexibility in deciding who is the best man to do a job regardless of his origins and classification.

A General Review of the Scientific Civil Service

311. The recommendations we have so far made in this Chapter are directed to the need for a more flexible and imaginative handling of scientific manpower than has been the case in the past. We are not hopeful, however, that the measures we have proposed can solve, as opposed to lighten, the problems we have considered. We have, therefore, turned our attention to various more radical proposals, mainly directed to enabling research staff to leave the Service for permanent employment outside.

312. One possibility, very attractive from the point of view of the national interest, would be to arrange a much closer relationship between Government research organisations and educational establishments, and to encourage many more scientific civil servants than at present to transfer at an appropriate stage in their career to universities, colleges of technology or schools. We therefore recommend that the practice of allowing scientific civil servants to undertake part-time teaching should be extended; and we see no objection to occasional secondments for limited periods to full-time teaching. We have already indicated the advantages of siting new Government research establishments near universities or colleges of technology. The reverse process should also not be overlooked.

313. Permanent transfers present no difficulties in the early stages of a scientific civil servant's career, and the opportunities will be increased if, as we recommend, more short-term and medium contracts are introduced. But difficulties arise once a man is promoted from Senior Scientific Officer to Principal Scientific Officer. At this stage transfer to school teaching would not be financially attractive at present even if the scientific civil servant were enabled to retire from Government service with an "earned" pension which is payable immediately. Transfer to a senior post in a university or college of technology is practicable under existing arrangements and does take place, and we hope that such transfers will be encouraged in appropriate cases.

314. We have also considered a number of other proposals of more general application; for example, early retirement schemes for the Scientific Officer Class (with pension rights in "cold storage", i.e. calculated to date of retirement but not payable until normal retirement age, at an earlier age than that (age 50) for the Civil Service generally); or the extension of "approved employment" transfer arrangements (which preserve the earned pensions of staff leaving the Service) to Scientific Officer Class staff who transfer to posts in industry. Our attention was also drawn to the analogy between the needs of scientific establishments and those of the Armed Services (where a flow in and out of relatively young men is obviously essential). This analogy would point to a system under which the bulk of research staff served under medium-term contracts with special compensation or pension terms.

315. All these proposals involve General Service problems outside our terms of reference or, alternatively, highly technical issues which require

detailed examination by staffing experts. We content ourselves with strongly recommending that they should be examined as part of a new general review, which we think is overdue, of the structure of the Scientific Civil Service (including the Experimental Officer and Assistant (Scientific) Classes). This would be primarily a matter for Treasury and Departmental officials but the advice of independent experts drawn from industry and the universities should be sought.

Summary of Recommendations

Civil Research and Development

CHAPTER III

Basic Research

1. The Directors of Government research establishments should be guided largely by the considerations set out in paragraphs 84 to 86 of this Chapter in deciding whether to undertake a new project in basic research. They should also consider whether certain of their established lines of basic research, if they are to continue, might not be transferred to a university (*paragraph* 90).

2. It should be accepted practice for Directors of research establishments to prepare rough time-tables when agreeing or reviewing programmes of basic research. A series of check points should then be agreed with the research workers concerned, and Directors should be systematic and rigorous in the reviews conducted at these agreed points (*paragraph* 101).

3. The freedom given to the Director and his senior staff in determining the content and reviewing the progress of programmes of basic research makes it essential to arrange for an independent review to be made from time to time by outside experts in the work covered by the particular establishment (*paragraph* 104).

CHAPTER IV

Applied Research and Development: The Selection of Projects

4. All Government organisations controlling establishments engaged in applied research and development should review their arrangements, both at Headquarters and at each of their research establishments, to see how far they provide satisfactory answers to the following questions (*paragraph* 119):—

(*a*) Are they adequately informed of relevant research being done or planned in other Government research establishments, universities, colleges of technology, industrial research associations and individual firms; and do they encourage organisations outside Government, either voluntarily or by extra-mural contracts, to fill in gaps in the overall research effort relevant to their respective fields?

(*b*) Are contacts with the administrative and executive branches of Government Departments, as users or potential users, adequate in practice as well as on paper?

(*c*) Is their knowledge of industry sufficient to enable them to understand the user's business and to help him to formulate his needs for applied research?

5. The practice should be developed of seconding staff for short periods from research establishments to administrative posts in Government Departments, and to work in industry, as part of a deliberately planned programme of training for selected staff (*paragraph* 120).

6. D.S.I.R. should be supported in its intention to undertake further reviews of other industries on the same lines as the recent reviews of the machine-tool and shipbuilding industries (*paragraph* 121).

7. Individual firms and the collective industrial organisations (employees as well as employers) should review the arrangements they have made to keep in touch with Government research establishments in the light of the following questions (*paragraph* 123):—

(*a*) On how many occasions during, say, the last three years have requirements been brought to the notice of Government research organisations?

(*b*) Is the machinery for formulating requirements satisfactory, and are there adequate links in this respect within the industry between those responsible for general policy and those responsible for research?

(*c*) Has consideration been given to the value, in certain circumstances, of seconding industrial research staff for limited periods to Government laboratories, i.e. making the arrangements we have suggested in paragraph 120 on a reciprocal basis?

8. Where the user or potential user is a Government Department which does not itself carry out research, the Department should ask itself whether it has got the necessary machinery for formulating its requirements in a manner useful to those who carry out, or might carry out, research on its behalf and, in particular, whether sufficient scientific staff is integrated with the administrative divisions of the Department to ensure that it is able to take account of advances in the applications of scientific knowledge in the formulation of policy (*paragraph* 127).

9. Those responsible for the selection (or approval of the selection) of individual projects should ask themselves the following questions (*paragraph* 129):—

(*a*) Has there been close collaboration between the user and those responsible for research and development in agreeing requirements and priorities and defining them as specifically as possible?

(*b*) Could the requirements be met by using or adapting techniques, processes or equipment already in existence or under development either in this country or abroad?

(*c*) Is the project technically feasible within an acceptable period of time, having regard to the current state of scientific knowledge?

(*d*) Has the best possible estimate been made of the cost of completing the project by a given date in terms of money and scientific manpower? Would it be advantageous to investigate the project more closely, e.g. by way of a project study (as defined in Chapter VII, paragraph 200) before a final commitment is made?

(*e*) Is this the first project of its kind? And if so, has allowance been made for the inexperience of those carrying out the feasibility and project studies?

(*f*) Would the work be best done in a Government establishment or elsewhere? Are there, within Government, resources available (in parti-

cular, staff of the necessary competence) to carry out the project? If not, is the project important enough to justify recruiting extra staff and paying for extra equipment? Should the project be carried out under an extra-mural contract placed with industry or with a university or a college of technology?

(*g*) Has the potential market—home or overseas—for the new equipment, technique or process been adequately considered?

(*h*) Where appropriate, has the estimated cost of producing the equipment or applying the technique or process, when developed, been taken into account? To what extent will industry have to learn to build up new manufacturing techniques?

CHAPTER V

Applied Research and Development: Control of Programmes and Dissemination of Results

10. An assessment of the results of research and development in progress and of likely future progress should always be carried out concurrently with a review of expenditure to date and of estimated future costs. Such dual assessments should be undertaken at intervals of not more than three to six months, and the results should be made available not only to higher management but also, as a way of encouraging cost-consciousness, to those who are directly responsible for individual projects (*paragraph* 138).

11. Departments and Research Councils whose research establishments do not review their work as suggested in paragraphs 137 to 139 of this Chapter should consider ways and means of devising regular reviews on these lines (*paragraph* 140).

12. Government organisations should examine the possibility of reducing the number of sub-heads in the annual estimates of individual research establishments in order to give Directors greater financial discretion (*paragraph* 152).

13. As a means of increasing the effectiveness of the dissemination of the results of research, much more should be done by D.S.I.R. and by the industrial research associations on the lines of "data sheets" such as those prepared by the Royal Aeronautical Society (*paragraphs* 160 and 161).

Defence Research and Development

CHAPTER VII

The Selection and Control of Projects

14. All defence projects which lead to the development of weapon systems should normally be processed through the following stages:—

(*a*) the formulation of a draft operational requirement (Staff Target), followed at an appropriate stage by an agreed operational requirement and the initial sketch of a technical specification;

(*b*) a feasibility study;
(*c*) a project study;
(*d*) and, finally, development itself.

Depending on the size and complexity of the project, one or more of these stages may involve little effort or may even be omitted. But those that are used should be clearly defined and formally recognised. All except the first could in some cases be undertaken under contract by industry, in co-operation with the Supply Department concerned. Where a project study is likely to proceed to a development contract, the Supply Department should consider the desirability, in the interests of continuity, of placing a holding contract of limited duration between the project study and the development contract (*paragraphs* 185 and 212).

15. The length of the tours of duty of senior officers in the Service Departments responsible for the formulation of operational requirements should be urgently reviewed by the Board of Admiralty, and the Army and Air Councils respectively. Consideration should be given to the possibility of filling such posts from the technical streams of the Services more frequently than is the case (*paragraph* 193).

16. The research staff in the research and development establishments of the Ministry of Aviation, War Office and Admiralty should have an appropriate formal association with the process of evolving operational requirements. The interchange between scientists in Headquarters posts and scientists in defence research and development establishments should be freer than is often the case (*paragraph* 194).

17. The responsibility for supervising a feasibility study should rest with a single official in the Supply Department (*paragraph* 197).

18. If industry is brought in at this stage two or more firms should be invited to compete in feasibility studies of limited duration (*paragraph* 198).

19. Project studies should be carried out for all major projects before a development contract is placed. During this stage money should be spent at the same rate as if the project had been, in fact, the first stage of a development contract (*paragraphs* 200, 201 *and* 202).

20. Whether carried out in a Government establishment or placed with industry a project study should be placed with only one group. If an extra-mural project-study contract is to be placed, it will be necessary to take into account the merits of the answers submitted to the preceding feasibility study and the known competence of the industrial undertakings concerned but, where practicable, suitable contractors should be invited to submit competitive proposals for a project study (*paragraph* 203).

21. Arrangements should be made to permit close contact between those responsible for carrying out a project study and the potential user. A single individual, assisted by a small steering committee set up by the Supply Department primarily concerned, should be made responsible for controlling the project study on behalf of the Government (*paragraph* 204).

22. A year's work at a cost of as much as 5 per cent of the total estimated research and development cost would not be inappropriate for an important defence project study (*paragraph* 206).

23. If, following a project study on the lines and on the scale envisaged, a decision is made to proceed with development, then every effort should be made to ensure that the momentum of the project is maintained and that only major technological, strategic or economic changes are allowed to interfere with its progress. The use of feasibility and project studies should go far to prevent the need for operating the break-clause except where these changes occur (*paragraphs* 186, 220 *et alia*).

24. A development contract should be a specific contract to meet a specific requirement on lines indicated by a preceding project study. It should include clear-cut arrangements about costs, a time-scale for the various phases, and a list of the major technical problems assembled in order of priority. These should be checked, as the work proceeds, by the responsible technical official in the Supply Department. Any major variation which would affect the concept, cost or timing of the project should be referred back for consideration to the level at which the original decision on the project-study report was taken, and to the D.R.P.C. if this body was initially involved or if subsequent developments justify reference to that Committee (*paragraph* 217 (i)).

25. If changes are introduced into the development of such magnitude as to necessitate the project being referred back to the D.R.P.C., that body should, if necessary, refer the whole project back to the Chiefs of Staff and the Minister of Defence (*paragraph* 217 (ii)).

26. As far as is technically and economically justifiable, the practice should be extended of making a single prime contractor responsible for the development of a complete project, subject to agreement with the Supply Department on the placing of sub-contracts (*paragraph* 217 (iii)).

27. The oversight of a development contract should, so far as the Government is concerned, be the responsibility of a single technical official in the Supply Department. Where necessary, he should be the Chairman of a team or management board on which should be represented the technical, financial, and contracts divisions of the Supply Department concerned, as well as the potential user and a representative of the prime contractor. Officials of relevant Government research establishments should also be brought into this monitoring process (*paragraph* 217 (iv)).

CHAPTER VIII

The Role of the D.R.P.C. and General Conclusions

28. The effort to harmonise the needs of the different Services should more often start before the formulation of the operational requirement and, as the cost of development is now so immense, every effort should be made to reconcile operational requirements so that a single design can satisfy more than one Service (*paragraph* 224).

29. In spite of the difficulties which have been experienced in achieving practical results, renewed efforts should be made to avoid wasteful duplication of effort in research and development amongst members of NATO and other countries of the Western world (*paragraphs* 225 *to* 227).

30. It is important that there should be no exceptions to the rule requiring reference to the D.R.P.C. or its Staff of all staff targets, operational requirements, feasibility studies and project studies, however small the probable cost of the project. More precision is desirable about which projects should come before the Committee, instead of being dealt with on their behalf by their Staff. The criterion for submission of a project to the Committee itself should be that its development is expected to cost £250,000 or more, or that it has important repercussions on defence policy (*paragraph* 235.)

31. The non-Service element in the full-time Staff of the D.R.P.C. should be strengthened by members of the Scientific Civil Service: a full-time administrative civil servant should also be on the Staff. The Chairman of the D.R.P. Staff should be on the staff of the Ministry of Defence and should be made a member of the D.R.P.C. itself (*paragraph* 236).

Organisation and Staff Management

CHAPTER IX

ORGANISATION

32. The Office of the Minister for Science should take on the responsibility of ensuring that proper weight is given in the siting of a new laboratory to such factors as the opportunities available for frequent personal contact between the research staff of the laboratory and other research workers (*paragraph* 247).

33. The Research Councils and Government Departments should examine the possibility of amalgamating or grouping small isolated establishments (*paragraph* 248).

34. Some means should be devised whereby Directors of at least the larger establishments could become effective participants in the meetings of the Research Councils and their main policy Committees (*paragraph* 251).

35. Where such arrangements do not already exist, Departments should give serious consideration to the formation of advisory bodies attached to their research establishments; or, as an alternative, to the appointment, for short periods, of independent specialists to act as consultants either on part or on the whole of an establishment's research programme (*paragraph* 255).

36. Consideration should be given to the use of *ad hoc* Visiting Groups (as is the practice in the A.R.C.) as a means of obtaining an independent check every five years or so on the work of research establishments (*paragraph* 256).

37. Those in charge of Government research organisations should consider with University authorities means whereby the two can achieve closer liaison (*paragraph* 257).

38. Government Departments generally should consider whether the development group technique can be applied to certain aspects of their work (*paragraph* 269).

CHAPTER X

Problems of Staff Management

39. The Treasury should discuss with Departments and staff representatives the possibility of giving Directors of certain research establishments greater powers than they have at present to recruit a proportion of their staff on short-term or medium-term contracts at all levels up to and including the Principal Scientific Officer grade (*paragraph* 288).

40. A greater effort should be made to attract scientists from outside the Service to Research Fellowships, the maximum value of which should be reviewed (*paragraph* 289).

41. Reporting officers should be reminded that it is in the interests not only of the Service but also of the probationer himself that anyone thought unlikely to have a reasonably successful career in Government research should not be retained in the Scientific Civil Service (*paragraph* 290).

42. The practice of employing research staff in a temporary capacity before they become established through the Civil Service Commission should be extended (*paragraph* 291).

43. All organisations whose staff are in the Scientific Civil Service, or who operate under similar conditions of service, should make greater use than in the past of existing procedures whereby the above-average research worker can be encouraged (*paragraph* 297).

44. Departments should review the standard of "proved ability" which they apply for promotion from S.S.O. to P.S.O. (*paragraph* 297).

45. The principle of flexibility in grading research posts should be recognised up to and including the P.S.O. grade (*paragraph* 299).

46. The principal organisations concerned should work out accepted practices in relation to the mobility of scientific staff as an important aspect of staff management and training (*paragraph* 305).

47. There should be more secondments between government research organisations and industry, the universities or colleges of technology and *vice versa* (*paragraph* 307).

48. All those responsible for the management of the Scientific Officer Class should review their present arrangements for training and job rotation within this Class (*paragraph* 309 (*a*)).

49. Departments, in consultation with the Inter-departmental Scientific Panel, should consider whether more transfers could be arranged of research staff in or before their middle years to posts normally filled by members of other Civil Service Classes (*paragraph* 309 (*b*)).

50. Everything possible should be done to encourage interchange between posts in the Scientific Officer Class and in the other Civil Service classes, in particular the Administrative Class (*paragraph* 310).

51. The practice of allowing scientific civil servants to undertake part-time teaching should be extended, and occasional secondments for limited periods to full-time teaching should also be considered (*paragraph* 312).

52. A number of proposals mentioned should be examined as part of a new general review, now overdue, of the structure of the Scientific Civil Service (including the Experimental Officer and the Assistant (Scientific) Classes) (*paragraph* 315).

S. ZUCKERMAN (*Chairman*).
G. EDWARDS.
W. JACKSON.
P. LINSTEAD.
A. A. PART.
G. W. ROBERTSON, (*Secretary*).

3*rd July*, 1961.

Appendices

LIST OF APPENDICES

I. List of witnesses and of Government organisations which submitted evidence.

II. Establishments, institutes, stations and units engaged in research and development wholly financed by Government.

III. The financial control of research and development in the Atomic Energy Authority.

IV. The size of research establishments, institutes, stations and units in terms of numbers of Scientific Officer Class Staff (or equivalents).

V. The Development Group of the Ministry of Education's Architects and Building Branch.

VI. Qualifications and duties of the Classes of the Scientific Civil Service.

VII. Salary structure of the Scientific Civil Service.

VIII. The Special Merit Promotion Scheme.

IX. Research Fellowships.

APPENDIX I

List of Witnesses and of Government Organisations which submitted Evidence

List of witnesses (in the order in which they were first seen by the Committee and showing the post held by them at that time)

Sir John Cockcroft, F.R.S. ...	Director of the Atomic Energy Research Establishment, Harwell (A.E.A.).
Sir Harry Melville, F.R.S. ...	Secretary, Department of Scientific and Industrial Research.
Sir Owen Wansbrough-Jones ...	Chief Scientist, Ministry of Supply.
Sir William Cook	Member for Development and Engineering, Atomic Energy Authority.
Sir George Gardner	Director of the Royal Aircraft Establishment, Farnborough (Ministry of Supply).
Sir Frederick Brundrett	Chief Scientific Adviser to the Minister of Defence.
Sir William Slater, F.R.S.	Secretary, Agricultural Research Council.
Sir Harold Himsworth, F.R.S. ...	Secretary, Medical Research Council.
Sir James Dunnett	Permanent Secretary, Ministry of Transport.
Mr. J. E. Hampson	Deputy Secretary, Ministry of Transport.
Mr. J. F. A. Baker	Chief Engineer (Highways), Ministry of Transport.
Dr. F. M. Lea	Director of the Building Research Station (D.S.I.R.).
Sir William Glanville, F.R.S. ...	Director of the Road Research Laboratory (D.S.I.R.).
Dr. F. Y. Henderson	Director of the Forest Products Research Laboratory (D.S.I.R.).
Air Marshal Sir Geoffrey Tuttle ...	Deputy Chief of the Air Staff, Air Ministry.
Air Chief Marshal Sir Claude Pelly	Controller of Aircraft, Ministry of Supply.
Sir Robert Cockburn	Controller of Guided Weapons and Electronics, Ministry of Aviation.
Mr. D. W. G. L. Haviland ...	Deputy Secretary, Ministry of Aviation.
Mr. W. J. Richards	Director of the Royal Radar Establishment (Ministry of Aviation).
Dr. J. Ferguson	Research Director, Imperial Chemical Industries.
Sir Arnold Hall, F.R.S.	Managing Director, Bristol Siddeley Engineering Co.
Sir Charles Harington, F.R.S. ...	Director of the National Institute for Medical Research (M.R.C.).
Mr. R. J. Halsey	Director of Research, Post Office.
Mr. F. C. Bawden, F.R.S. ...	Director of Rothamsted Experimental Station (A.R.C.).
Sir Bruce Fraser	Third Secretary, H.M. Treasury.
Mr. D. R. Serpell	Under Secretary, H.M. Treasury.
Mr. R. W. B. Clarke	Third Secretary, H.M. Treasury.
Mr. W. O. Humphreys	Director of Research and Technical Development, General Electric Company.
Mr. W. W. Morton	Third Secretary, H.M. Treasury.
Mr. C. S. Bennett	Principal, H.M. Treasury.

Sir Cyril Hinshelwood, F.R.S. ...	President, Royal Society.
Sir William Hodge, F.R.S. ...	Physical Secretary, Royal Society.
Sir Gerard Thornton, F.R.S. ...	Foreign Secretary, Royal Society.
Dr. D. C. Martin	Assistant Secretary, Royal Society.
Mr. E. M. Nicholson	Director-General, Nature Conservancy.
Sir Gordon Sutherland, F.R.S. ...	Director of the National Physical Laboratory (D.S.I.R.).
Sir William Strath	Permanent Secretary, Ministry of Aviation.
Admiral Sir Peter Reid	Third Sea Lord and Controller, Admiralty.
Sir John Carroll	Deputy Controller (Research and Development) Admiralty.
Mr. Stanley Mayne	General Secretary of the Institution of Professional Civil Servants (I.P.C.S.).
Mr. T. H. Profitt	Deputy Secretary, I.P.C.S.
Mr. J. F. Fry	I.P.C.S.
Dr. H. S. Turner	I.P.C.S.

Departments and Organisations from which information was received in answer to a questionnaire sent out by the Committee and also in response to direct enquiries

Admiralty.

Ministry of Agriculture, Fisheries and Food.

Ministry of Defence.

Post Office.

Ministry of Power.

Ministry of Supply (research and development responsibilities later taken over by Ministry of Aviation and War Office).

Agricultural Research Council.

Department of Scientific and Industrial Research.

Medical Research Council.

Nature Conservancy.

Atomic Energy Authority.

We should also like to record the help we have received from Mr. R. N. Quirk of the Office of the Minister for Science and from Mr. D. A. Smith of the same Office, both of whom spent many hours in work on our behalf.

APPENDIX II

ESTABLISHMENTS, INSTITUTES, STATIONS AND UNITS ENGAGED IN RESEARCH AND DEVELOPMENT WHOLLY FINANCED BY GOVERNMENT

GOVERNMENT DEPARMENTS

	*Number of Scientific Officer Class Staff in post**
1. Civil research and development	
(a) *Admiralty*	
Royal Observatory, Herstmonceux	17
Nautical Almanac Office, Herstmonceux	5
(b) *Air Ministry*	
Meteorological Office (research staff only, mainly at Headquarters)	62
Outstations: Malvern (radar), Meteorological Research Flight, and three research observatories	
(c) *Ministry of Agriculture, Fisheries and Food*	
Royal Botanic Gardens, Kew	26
Veterinary Laboratory, Weybridge	68
Outstation, Lasswade, Scotland	6
Fisheries Laboratory, Lowestoft (small outstations at Burnham-on-Crouch and Conway)	35
Salmon and Freshwater Laboratory, London ...	6
Plant Pathology Laboratory, Harpenden	23
Infestation Control Laboratory, Guildford, Surrey ...	19
Aberdeen Research Establishment (food science)† ...	15
London Laboratories (food science)	11
National Agricultural Advisory Service (applied research, development and trials)	
11 Experimental Husbandry Farms	2 to 8 (at each)
7 Horticultural Stations	3 to 8 (at each)
National Institute of Agricultural Botany (development work and trials)	
Headquarters, Cambridge	38
14 Regional Trial Centres	1 (at each)
(d) *British Museum (Natural History)*	82
(e) *British Museum*	
Research laboratory	1

* Including equivalents; professional engineers, veterinary, medical, forestry and agricultural staff. The figures include a small number of scientists who are not engaged on research and development, e.g. in the Government Chemist's Laboratory and in the Nature Conservancy.

† Closed in 1961.

	Number of Scientific Officer Class Staff in post
(f) *Colonial Office**	
Overseas Geological Surveys (mineral resources and geophysics), London	22
Outstation (photogeology); Tolworth, Surrey† ...	6
(g) *Forestry Commission*	
Research Station, Farnham, Surrey	31
(h) *Home Office*	
Seven Regional Forensic Science Laboratories (some research and development is carried out in each)	3 to 5 (at each)
(i) *Post Office*	
Dollis Hill Research Station (telecommunications, postal services)	238
(j) *Ministry of Power*	
Safety in Mines Research Establishment, Sheffield ...	52
(k) *Ministry of Works* (administrative responsibility only)	
Royal Botanic Gardens, Edinburgh	7
(l) *Scottish Departments*	
Marine Laboratory, Torry, Aberdeen (fisheries research)	25
Outstation: Freshwater Fisheries Laboratory, Pitlochry, Perthshire	6
Royal Observatory, Edinburgh	5
	Total 417

2. Defence research and development‡

Admiralty

Admiralty Surface Weapons Establishment, Portsdown, Portsmouth.
Admiralty Underwater Weapons Establishment, Portland, Dorset.
Services Electronics Research Laboratory, Baldock, Herts.
Admiralty Research Laboratory, Teddington, Middx.
Admiralty Materials Laboratory, Holton Heath, Dorset.
Naval Construction Research Establishment, Dunfermline, Fife.
Admiralty Engineering Laboratory, West Drayton, Middx.
Admiralty Compass Observatory, Slough, Bucks.
Admiralty Experiment Works and Admiralty Fuel Experiment Station, Hasler, Hants.
Admiralty Oil Laboratory, Brentford, Middx.

* These responsibilities now fall on the Department of Technical Co-operation which came into being on the 24th July, 1961.

† Attached to the Directorate of Overseas (Geodetic and Topographical) Surveys.

‡ For reasons of security the number of staff in individual establishments is not shown.

	Number of Scientific Officer Class Staff in post
R.N. Physiological Laboratory, Alverstoke, Hants.	
Six small units engaged on testing, trials and inspection.	
War Office	*Total* 437
Armaments Research and Development Establishment, Fort Halstead, Kent.	
Fighting Vehicles Research and Development Establishment, Chertsey, Surrey.	
Chemical Defence Research Establishment, Porton, near Salisbury.	
Microbiological Research Establishment, Porton, near Salisbury.	
Military Engineering Experimental Establishment, Christchurch, Hants.	
Clothing and Stores Experimental Establishment, Farnborough, Hants.	
Nine small units (testing and trials).	
Ministry of Aviation	*Total* 1,083
Royal Aircraft Establishment, Farnborough, Hants. (air/guided weapons/radio).	
R.A.E. outstations (the largest at Cardington, Bedford).	
Royal Radar Establishment, Malvern, Worcs.	
National Gas Turbine Establishment, Pyestock, Hants.	
Explosives Research and Development Establishment, Waltham Abbey, Essex.	
Signals Research and Development Establishment, Christchurch, Hants.	
Aeroplane and Armament Experimental Establishment, Boscombe Down, Wilts.	
Rocket Propulsion Establishment, Westcott, Bucks.	
Four small units (testing and trials).	
Air Ministry	
Institute of Aviation Medicine, Farnborough, Hants.	

RESEARCH COUNCILS

Agricultural Research Council	
Rothamsted Experimental Station, Harpenden, Herts.* (problems of arable agriculture except plant breeding)	103
National Institute for Research in Dairying, Reading, Berks.* (milk production and utilisation)	71

* State-aided Institutes.

	Number of Scientific Officer Class Staff in post
Rowett Research Institute, Bucksburn, Aberdeenshire* (animal nutrition)	50
East Malling Research Station, Maidstone, Kent* (fruit plants)	48
Macaulay Institute for Soil Research, Aberdeen* ...	47
Agricultural and Horticultural Research Station, Long Ashton, Bristol*	36
Institute of Animal Physiology, Babraham, Cambridge	33
National Institute of Agricultural Engineering, Silsoe, Beds.*	31
Welsh Plant Breeding Station, Aberystwyth*	29
Grassland Research Institute, Maidenhead, Berks.*	27
Pest Infestation Laboratory, Slough, Bucks.	25
Hannah Dairy Research Institute, Kirkhill, Ayr* (production and handling of milk)	25
National Vegetable Research Station, Wellesbourne, Warwick*	24
Low Temperature Research Station, Cambridge (storage of meat and fruit)	24
Rothamsted Soil Survey, Harpenden, Herts.	24
Glasshouse Crops Research Institute, Littlehampton*	24
John Innes Institute, Bayfordbury, Hertford, Herts.* (plant genetics and physiology)	24
Research Institute (Animal Virus Diseases), Pirbright, Surrey*	23
Animal Diseases Research Association, Edinburgh* ...	20
Animal Breeding Research Organisation, Edinburgh	19
Scottish Horticultural Research Institute, Mylnefield, by Dundee*	18
Plant Breeding Institute, Trumpington, Cambridge*	16
Poultry Research Centre, Edinburgh	15
Field Station, Compton, Berks. (diseases of farm animals)	14
Scottish Plant Breeding Station, Portlandfield, Midlothian*	12
Hill Farming Research Organisation, Edinburgh* ...	11
Radiobiological Laboratory, Letcombe Regis, Berks.	11
Houghton Poultry Research Station, Houghton, Huntingdon*	9
Ditton Laboratory, Lankfield, Kent (fruit storage) ...	9
Weed Research Organisation, Begbroke Hill, Oxfordshire	8
National Institute of Agricultural Engineering, Scottish Station, Howden, Midlothian*	6
Hop Research Centre, Ashford, Kent*	5
Twelve units attached to universities; none with more than a dozen staff as defined in this Appendix, most with half that number or less; Animal Genetics, Biometrical Genetics, Embryology, Experi-	

* State-aided Institutes.

	Number of Scientific Officer Class Staff in post
mental Agronomy, Insect Physiology, Microbiology, Plant Morphogenesis and Nutrition, Plant Physiology, Reproductive Physiology and Biochemistry, Soil Physics, Statistics and Systemic Fungicides. In addition there are three other small units or groups concerned with Farm Buildings, Virus Research and Statistics	64
Department of Scientific and Industrial Research	
National Physical Laboratory, Teddington, Middx. (aerodynamics, physics, control mechanisms, light, mathematics, metallurgy, ship design, standards) ...	164
Geological Survey and Museum, London	107
Building Research Station, near Watford, Herts. ...	73
Road Research Laboratory, West Drayton, Middx. ...	82
National Chemical Laboratory, Teddington, Middx. (extraction and corrosion of metals, pure elements and compounds, new materials, analytical research and services)	57
National Engineering Laboratory, East Kilbride, Glasgow	52
Laboratory of the Government Chemist, London (concerned with revenue control and general analytical work)	55
Warren Springs Laboratory, Stevenage, Herts.* (mineral processing, chemical engineering, atmospheric pollution and human sciences)	37
Tropical Products Institute, London	31
Radio Research Station, Slough, Bucks. (radio and space research)	26
Torry Research Laboratory, Torry, Aberdeen (storage and processing of fish)	25
Water Pollution Research Laboratory, Stevenage, Herts.*	19
Forest Products Research Laboratory, Aylesbury, Bucks.	19
Hydraulics Research Laboratory, Wallingford, Berks.	16
Fire Research Station, Elstree, Herts.†	11
Medical Research Council	
National Institute for Medical Research, Mill Hill	125
Radiobiological Research Unit, Harwell	39
Seventy-four units with less than 20 scientific staff, the majority with less than 10, and attached, with only a few exceptions, to universities or hospitals. These units cover the following sub-	

* These two Laboratories are on different sites separated by a main road and railway line.

† The Fire Insurance Companies who are members of the Fire Offices Committee together with all the independent Mutual Offices halve the total cost to the Government of the Fire Research Station.

	Number of Scientific Officer Class Staff in post
jects (the number of units in each subject being in brackets):— Clinical medicine (1), specific diseases (6), endocrinology (2), radiation research (7), industrial and social medicine (10), nutrition and metabolism (3), genetics (7), psychology and psychiatry (9), haematology (4), biochemistry (1), biophysics (2), microbiology (1), chemotherapy (2), virus research (3), neurology (1), ophthalmology (2), experimental pathology (1), tropical medicine (4), otology (2), obstetrics (1), dental research (1), physiology (1), carcinogenic substances (1), laboratory animals (1) and statistics (1)	489
Institutes, etc., receiving substantial support by block grants from the Medical Research Council:—	
Institute of Cancer Research*, Royal Marsden Hospital, London	160
Royal Beatson Memorial Hospital, Cancer Research Department, Glasgow*	10

Nature Conservancy (including conservation staff)

Edinburgh Headquarters	11
Merlewood Research Station, Grange-over-Sands, Lancs.	9
London Headquarters	7
Furzebrook Research Station, Wareham, Dorset ...	7
Wales Headquarters and Research Station, Bangor, Caerns.	5
Monks' Wood Experimental Station, St. Ives, Hunts.	4
Speyside Research Station, Aviemore, Inverness-shire	3
Research Unit attached to Aberdeen University ...	3
East Anglian Regional Office, Norwich	2
Midland Regional Office, Shrewsbury, Shropshire ...	1
South Wales Regional Office, Department of Zoology, University College of Swansea	1

Development Commission

Scottish Marine Biological Association, Millport and Edinburgh	19
Marine Biological Association Laboratory, Plymouth	17
Freshwater Biological Association Laboratory, Windermere	16

* Also receives support from the British Empire Cancer Campaign.

	Number of Scientific Officer Class Staff in post
About two-thirds of the cost of the following laboratories is met by the Development Commission :—	
University of Liverpool Marine Biological Station, Port Erin, Isle of Man	6
Kings College, Newcastle-on-Tyne, Dove Marine Laboratory	4
National Institute of Oceanography*	27

ATOMIC ENERGY AUTHORITY†

Research Group

Atomic Energy Research Establishment, Harwell, Berks.

Culham Laboratories (controlled thermonuclear fusion)—under construction.

Radiochemical Centre, Amersham, Bucks. (developing, processing and selling radioactive isotopes).

Wantage Radiation Laboratory, Berks. (applications of radioactive isotopes).

Woolwich and Chatham (chemical analytical services).

The Reactor Group

Atomic Energy Establishment, Winfrith, Dorset.

Dounreay Experimental Research Establishment, Caithness.

Laboratories at Springfields, Culcheth and Risley in Lancashire and at Windscale, Cumberland.

Weapons Group

Atomic Weapons Research Establishment, Aldermaston, Berks.

Three small units (trials).

National Institute for Research in Nuclear Science, Rutherford Laboratory, Harwell, Berks.	60

* Financed mainly by grants from the Development Fund, the Admiralty and the Colonial Office

† For reasons of security the number of staff is not given.

APPENDIX III

THE FINANCIAL CONTROL OF RESEARCH AND DEVELOPMENT IN THE ATOMIC ENERGY AUTHORITY

1. This Appendix gives a broad explanation of the method of control of research and development work, in terms of both manpower and money, followed in the Reactor Group of the Atomic Energy Authority. The procedures described are subject to review and revision as circumstances change and experience is gained in applying the system.

THE MASTER PROGRAMME

2. The Reactor Development Policy Committee, under the Chairmanship of the Member for Reactors, approves each year a Master Programme within the framework of the policy laid down by the Authority and the resources available as estimated in the 5 year expenditure forecasts. The Master Programme identifies the main reactor projects and sets interlocking target dates for the completion of subsidiary investigations. The major dates are agreed by a process of discussion and estimation between the Technical Directors concerned and through them, the Research Managers at the working level.

AUTHORISATION SHEETS

3. Each reactor project is broken down into major areas of work covering a definable technical objective, for each of which a Director is made technically and financially responsible. Care is taken that each area is wide enough to allow the proper delegation of detailed control to the Director and establishment concerned. An authorisation sheet is then prepared by the responsible Director for each area of work. This sheet shows the allocation of tasks to the various establishments within the Group, to other Groups of the Authority and to Industry. For the tasks allocated to Reactor Group esablishments, estimates are made of the professional staff requirements and financial costs for the current and the succeeding year, together with a broad estimate of the manpower and money required to complete the task if the work is expected to take longer than two years. For other Groups and Industry, cost figures only are estimated. The responsible Director has assistance from the Group Finance Branch and Technical Secretariat in the preparation of the estimates. These organisations are also responsible for ensuring that total allocations do not exceed available resources.

4. Completed authorisation sheets are then presented by the responsible Director to the Reactor Development Policy Committee for approval of the technical content of the proposals and to the Reactor Group Board of Management for the authorisation of the required resources for either one or two years ahead, depending upon the degree of confidence felt in the continuing need for the work. No work is authorised for more than two years ahead.

PREPARATION OF BUDGETS

5. Establishments first prepare separate Manpower Planning Schedules and, on a fully costed basis, Operating and Capital Expenditure Budgets for the tasks allocated to them in the Authorisation Sheets. The Group Finance Branch works out the Group's annual Cash Budget from these for submission to the Authority in the form of Estimates after approval by the Group Board of Management.

6. Once the Group Estimates have been approved, the Manpower Schedules and Expenditure Budgets are brought up to date and issued for each establishment before the beginning of the financial year.

CONTROL AGAINST AUTHORISATION SHEETS

7. Annual expenditure and total costs incurred on any area of work must not exceed the total on the relevant sheet authorised by the Board of Management. Financial control is maintained by the provision to the various levels of Management of regular reports containing the same kinds of information as those used in compiling programmes and budgets initially. These take the form of Manpower Returns and Cost Statements designed to show variances from authorisations. Attention is thus drawn to activities at variance with Programmes and Authorisations, rather than to those which are proceeding on programme and as budgeted, so that correct action can be taken to prevent commitments exceeding authorisations.

REVIEW

8. Each Authorisation Sheet is reviewed at least once a year by the Reactor Development Policy Committee at set dates. The review covers the technical progress towards the objective, the commitments and expenditure incurred, and the cost of completion compared to the estimate. At a Review the work may be terminated or the allocation of the resources changed according to the technical needs prevailing at the time. Within the total of each Authorisation Sheet, it is within the discretion of the responsible Director to readjust his allocated resources as the work proceeds, such reallocations being noted and explained at the Review. But the responsible Director concerned may call for the Review of any Authorisation Sheet at any time if unforeseen developments occur; and if there is any risk of the total being exceeded, the facts must be reported at once to the Board of Management by the Director. If he considers that increased resources are necessary, the responsible Director must make definite proposals for their provision—either by stopping or by slowing down less important work—and obtain revised authorisation before proceeding.

CONTROL OF CAPITAL EXPENDITURE

9. A separate control is imposed before new capital expenditure can be made. After general authorisation by inclusion on an Authorisation Sheet the Director responsible prepares a Capital Expenditure Proposal, giving full details of the project and its justification, the estimated total cost and an estimate of expenditure by years under various headings, together with the current budget provision and a construction programme.

10. Each responsible Director has been given delegated authority to sanction capital projects up to certain specified limits within budget allocations previously approved by the Group Board of Management. Beyond these limits he must submit proposals to the Group Board of Management, which will in turn submit them to London or the Authority if they are beyond Group powers.

11. On approval of a Capital Expenditure Proposal, an Authority to Proceed is issued by the Group Finance Branch. This gives a description of the scheme and details of any qualifications which may have been made in giving sanction. Detailed records are kept of the expenditure of money and effort on each scheme and regular reviews are made in the light of the physical progress achieved, the commitments and expenditure incurred, and the cost of completion.

EXTRA-MURAL WORK

12. Contracts for extra-mural work require individual formal approval in a manner similar to that for capital projects. Each contract is assigned for technical and financial administration and review to the establishment most closely associated with the work involved, which is also responsible for keeping a record of commitments and expenditure incurred.

The size of research establishments, institutes, stations and units in terms of numbers of Scientific Officer Class Staff (or equivalents)

Number of Scientific Officer Class Staff (or equivalents)	Number of Establishments, etc.													
	M.R.C.		A.R.C.				D.S.I.R.		Admiralty		War Office		Aviation	
	Institutes and Units	Per cent. S.O. Class Staff	Institutes	Units	Total	Per cent. S.O. Class Staff	Stations	Per cent. S.O. Class Staff	Estabs. and Units	Per cent. S.O. Class Staff	Estabs. and Units	Per cent. S.O. Class Staff	Estabs. and Units	Per cent. S.O. Class Staff
100 or more ...	1		1	—	1		2		1		1		2	
60–99	0	25	1	—	1	46(1)	2	85	3	78	1	93	3	97
30–59	1		6	—	6		5		—		3		3	
20–29	0		11	—	11		2		1		—		—	
10–19	18	75	8	—	8	54(1)	4	15	2	22	—	7	—	3
less thao 10 ...	56		5	15	20		—		10(2)		10(2)		4(2)	
Total number of estabs. or units	76(3)	100	32	15(3)	47	100	15	100	17	100	15	100	12	100
Total staff as defined above ...	653		841	64	905		774		417		437		1,083	

General Note: Establishments with more tban 100 S.O. Class staff (or equivalents) are as follows:—

A.R.C.: Rothamsted (103).
M.R.C.: National Institute for Medical Research (125).
D.S.I.R.: National Physical Laboratory (164), Geological Survey and Museum (107).
Ministry of Aviation: Royal Aircraft Establishment, Farnborough; Royal Radar Establishment.
War Office: Armameots Research and Development Establishment.
Admiralty: Admiralty Surface Weapons Establishment.

Notes: (1) If A.R.C. units are excluded, these figures would be 50 per cent.
(2) These smaller units are mainly concerned with trials and testing.
(3) A.R.C. and M.R.C. units are generally attached to universities or hospitals.

APPENDIX V

THE DEVELOPMENT GROUP OF THE MINISTRY OF EDUCATION'S ARCHITECTS AND BUILDING BRANCH

History

1. The development Group of the Architects and Building Branch of the Ministry of Education was set up in 1949. It has since completed nine major building projects, contributed to seventeen studies of different aspects of educational building (the "Building Bulletin" series), and conducted a large number of smaller development projects (e.g. school furniture, lighting, sanitary ware). It is now engaged on four major projects, and seven new Building Bulletins are in preparation.

The Ministry's Task

2. The Ministry of Education approves, for each local education authority, an annual programme of major building projects (i.e., those costing over £20,000 each). In England and Wales as a whole, the 1960-61 programme contains principally some 800 projects for primary and secondary schools with some 110 projects for further education. A substantial number of projects for teacher training colleges and some for special schools for handicapped children are also included. The total value of the programme to be started in 1960-61 is over £80 million. In addition, minor projects (i.e. those costing less than £20,000 each) to the value of about £18 million will be started.

3. Local education authorities (counties and county boroughs) employ their own or private architects to design and build these projects. The Minister of Education must, however, approve the plans and cost of all major, and some minor, projects.

4. So that the Minister's powers of control may be exercised constructively, local education authorities are informed *before* they start the design of these projects of

(1) the minimum standards of area, performance, amenity, etc. with which their projects must conform, and

(2) the maximum cost which they must not exceed.

Any project which meets these two conditions will receive the Minister's approval.

5. This procedure is intended to combine a simple and speedy central control with the maximum of local freedom. But it requires the Minister to make up his mind about right standards and reasonable levels of cost and to annouce these publicly.

The Nature of the Ministry's Development Work

6. The Ministry's development work normally excludes basic research, although occasionally it has been possible to use a development project to test in a practical way certain theoretical concepts (e.g. the plastic theory of structure advanced by Professor Baker of Cambridge University).

7. Applied research is also not directly included. But central to the Group's work is a need (i) to know of the results of applied research (e.g. D.S.I.R.'s Building Research Station work on lighting, colour, heating, sound), (ii) to exploit these results as rapidly and as widely as possible (e.g. by designing suitable light fittings, colour ranges, heating systems, sound insulation) and (iii), where gaps in knowledge are known and need filling, to stimulate applied research in those directions (e.g. performance standards for school furniture, foundation design, site output and productivity).

8. Further points about the Ministry's development work are as follows:—

(1) Its underlying motive power might be called constructive scepticism: scepticism because it seeks first to question all accepted assumptions; constructive because it believes that, by analysis and experiment, a better solution can often be found than the best current answer.

(2) It tries to tackle problems as a whole and not piecemeal. A development project takes the form, for example, of a complete school or college of further education. Although this entails specialist investigations into general or specific aspects of design, structures, services, finishes, etc., these investigations are comprehended within the project as a whole and are not separate projects in themselves. Such development work for education in the U.S.A. as has come to the notice of the Ministry of Education is fragmented in this latter way. There, component problems are investigated more deeply but in isolation, and therefore divorced from the inescapable pressure to compromise that "real" building—and British economic circumstances—dictates.

(3) Its objectives are controlled and finite. There is no question of "going on" or "spending on" (men, time or money) until a perfect or ideal solution is found. Objectives are clearly and realistically defined at the outset of a project: for example, in the case of a secondary modern school, (*a*) design at 69 sq. ft. per pupil; (*b*) design a series of prefabricated standardised structural components for building up to four storeys in height; (*c*) study particularly the dining arrangements and the science accommodation; (*d*) finish the building by a given date; (*e*) comply with the Ministry's standards and cost limits. The development team thus organise the time and brains available to give optimum results within the given terms of reference.

(4) When the Ministry wishes to undertake a development project it asks a local education authority to allow it to build a project which that authority would have needed anyhow and is about to submit for inclusion in an approved building programme. The authority then employs the Development Group as though they were private architects, and on the same financial basis.

(5) The Ministry has always insisted that its development projects must be subject to the same financial discipline as the ordinary projects of local authorities. It has steadfastly refused to let development contracts, e.g. for prototypes, to manufacturers on the ground that the assured prospect of a succession of large educational programmes will offer the successful developer ample opportunities for recouping his development expenditure. Apart from two or three small payments to the Building Research Station, almost the only expenditure by the Ministry on development since the Group was set up has been the normal salaries of the staff concerned and this has been recouped by charging normal R.I.B.A.-scale fees to the local education authorities for whom development projects have been carried out.

(6) The Group is divided into three or four teams, one for each project in hand. Each team includes, in addition to its architectural and administrative leaders, quantity surveyors and H.M. Inspectors. Designers, manufacturers, suppliers and builders are co-opted into the team as necessary.

(7) Effective intercommunication, which is essential between these different skills within a development team, is assisted by means of the technique (specially devised by the Ministry's Development Group and now beginning to be applied outside educational building) of cost analysis and cost planning. These provide vocabulary, grammar and concepts which laymen and professionals can understand and use as a basis for collaboration.

(8) The work of the Group stands or falls by its quality. Appointments to its staff are therefore made with great care. Developers are "naturals", and comparatively rare. They tend to be what they are by reason of character and temperament, rather than as a result of their education or professional training. Perhaps their most important characteristic, apart from professional skill, is a sustained spirit of curiosity and enquiry, coupled with a strong desire to see their work produce practical results.

Results Achieved

9. Before the Group was set up in 1949 the average cost per place of a primary school was about £200 and of a secondary school about £320. If schools of the same kind had gone on being built, and if their cost had been carried up each year by rising building costs, they would today cost about £332 and £530 respectively. In fact, however, the average costs per place (on tender and in the first six months of 1960) were £153 and £265 respectively. Thus, a school place is some 20 per cent cheaper today in cash terms, and about 50 per cent cheaper in real terms, than it was in 1949. It is true that these schools are about 40 per cent smaller in total area, but the amount of productive teaching space within the total area has remained the same and in some cases been increased. This approach, coupled with a determined attack on costs, using the systematic techniques of cost analysis and planning referred to in the previous paragraph, have been the two principal means of achieving these results.

The Dissemination of Results

10. The ideas and techniques evolved and the results achieved by the Group are propagated by Building Bulletins and other means so that nearly all local authorities and their architects now accept them as first principles. Much of the Group's work, e.g. on cost planning, colour, fire precautions, pre-stressed concrete components and heating systems, is now being applied outside educational building.

APPENDIX VI

QUALIFICATIONS AND DUTIES OF THE CLASSES OF THE SCIENTIFIC CIVIL SERVICE

A. The Scientific Officer Class

(i) In general, this class comprises university graduates with first or second class honours degrees (including holders of the Diploma of Technology) recruited direct from the universities (at Scientific Officer level) or with at least three years' research experience (at Senior Scientific Officer level).

(ii) This class, the highest of the three scientific classes, is the initiating, directing and inventive brain for all scientific research, design and development work which is pursued within the Civil Service. It is supported and aided by the Experimental Officer Class and the Assistant (Scientific) Class. It is essential that the Scientific Officer Class shall be employed only on the high quality work for which it is intended. No precise definition of the duties of the various grades is possible. Broadly speaking, the duties of the grades above Principal Scientific Officer include responsibility for the direction and administration of scientific

work, while the Principal Scientific Officer and lower grades concentrate on the scientific work itself. But posts of Senior Principal Scientific Officer and above may, with Treasury authority, be created for individual research workers of specially outstanding quality (see Appendix VIII).

B. The Experimental Officer Class

(i) In general, entry to this class is open to holders of two science subjects at G.C.E. advanced level, Higher National Certificate or a University Pass Degree or its equivalent.

(ii) The Experimental Officer Class is the main support of the scientific officers of the Civil Service. It provides assistance on scientific research, design and development work, and the executive staff for work on which the scientific principles and practice have been laid down. Under the general guidance and directions of the Scientific Officer Class, Experimental Officers assist in new investigations, particularly in their detailed organisation and execution. They also take responsibility for both the theoretical and practical aspects of work requiring the application of established scientific principles.

(iii) Occasionally, Experimental Officers may be used in appropriate circumstances in support of professional engineers and chemists employed on work more immediately concerned with production.

C. The Assistant (Scientific) Class

(i) In general, entry is open to those with four passes at G.C.E. ordinary level (including one science subject).

(ii) *General.* This class supplements and relieves the Experimental Officer Class in the detailed work of organisation, construction, observation, calculation and report, devolved for the ultimate relief of the fully-qualified professional specialist. Local titles more closely descriptive of departmental work (e.g. Meterological Assistant) may be adopted departmentally.

(iii) *Assistant (Scientific).* The lower range of duties of the grade includes simple experimental work involving the preparation of materials and apparatus, observation and computation. It also includes routine jobs such as cleaning apparatus and simple repetitive tests. In the middle and upper ranges, Assistants (Scientific) are responsible under supervision and instruction for making and setting up apparatus and conducting experiments and tests, including subsequent computation and written factual report. They may also do skilled work in particular laboratory crafts, such as glass blowing.

(iv) *Senior Assistant (Scientific).* The duties of the Senior Assistant (Scientific) grade include the immediate supervision of small groups of Assistants, and the preparation and use of apparatus and materials requiring the highest skill or wide experience. The grade is not restricted to supervisory functions, and Senior Assistants may be employed mainly or entirely on highly skilled individual work.

D. Recruitment

Establishment in the various classes of the Scientific Civil Service can only normally be attained through the Open Competitions held throughout each year by the Civil Service Commission; exceptionally, established members of the Experimental Officer Class or of the Assistant (Scientific) Class can, if they are over 31 years of age, be promoted departmentally to a higher Class.

APPENDIX VI

SALARY STRUCTURE OF THE SCIENTIFIC CIVIL SERVICE (AT 1st JANUARY, 1961)

	Salary £	Staff in post at 1/4/1960 Govt. Depts.	A.R.C.
Chief Scientific Officers and above, salaries ranging from ...	3,800to7,000	71	10
Deputy Chief Scientific Officers ...	3,125—3,450	146	30
Senior Principal Scientific Officers ...	2,650—3,000	441	86
Principal Scientific Officers... ...	1,716—2,418	1,357	279
Senior Scientific Officers ...	1,342—1,654	975	341
Scientific Officers ...	738—1,222	415	159
	TOTALS ...	3,405	905
	£		
Chief Experimental Officers ...	1,976—2,288	121	2
Senior Experimental Officers ...	1,508—1,872	1,340	85
Experimental Officers ...	1,087—1,336	3,516	297
Assistant Experimental Officers ...	458— 983	1,377	284
	TOTALS ...	6,354	668
	£		
Senior Assistants (Scientific) ...	811—1,082	1,086	116
Assistants (Scientific) ...	333— 723	4,399	813
	TOTALS ...	5,485	929

APPENDIX VIII

THE SPECIAL MERIT PROMOTION SCHEME

1. The Special Merit Promotion Scheme has been an outstanding feature of the Scientific Civil Service from the beginning, and is administered by a Sub-Committee of the Inter-departmental Scientific Panel.

2. The Scheme recognises that the orthodox hierarchy of graded posts, found throughout the Civil Service, is not always appropriate to scientific research work.

3. The higher the grade of a post in the Civil Service, the greater in general is its managerial content. To a large extent this factor determines the number and grading of the higher posts. For example, on organisational grounds and, therefore, quite independently of the particular abilities of individuals filling the various posts, a given block of research work might be under the charge of a Deputy Chief Scientific Officer (D.C.S.O.). He might have reporting to him, say, three Senior Principal Scientific Officers (S.P.S.O.), each of these being in charge of a sub-division of work and responsible for supervising lower grades of the Scientific Officer Class, members of the Experimental Officer Class, and the Assistant (Scientific) Class. This would form an orthodox hierarchical organisation. A Principal Scientific Officer in such an organisation could not be promoted to S.P.S.O. until a vacancy occurred in one of the S.P.S.O. posts. Similarly, the S.P.S.O.s could not be promoted until D.C.S.O. posts fell vacant.

4. Such a system inevitably had two unfortunate effects. First, an outstanding research worker who had little or no managerial ability was unlikely to be pro-

moted into the higher grades; second, if an outstanding research worker possessed the necessary managerial ability and was promoted, he inevitably found himself diverted from his research work by the managerial responsibilities associated with the higher posts.

5. The system of special merit promotion was designed to enable outstanding research workers to be rewarded for their work by promotion, but in a way which overcame these drawbacks.

6. Under the Special Merit Promotion Scheme research workers are judged for promotion entirely on the basis of their ability as research workers. Posts in the higher grades are created for them outside the normal organisational hierarchy, i.e. outside the normal complement. In the example given in paragraph 3 above it would be possible to create another D.C.S.O. post within the same block of research work to allow one of the S.P.S.O.s to be promoted.

7. Scientists must be at least Principal Scientific Officers before they can be considered for special merit promotion, but posts at all higher levels can be created under the scheme. The Treasury has never laid down any limit to the number of posts that can be made in this way, provided that they are counted within the total manpower ceiling, covering all staff, that has been agreed for each Department.

8. The special merit post is abolished when the incumbent leaves the Service or is promoted to the hierarchical system.

9. The Inter-departmental Scientific Panel's Sub-Committee on special merit promotion consists of individuals appointed among the higher ranks of the Scientific Civil Service and from outside the Service.

10. The Sub-Committee, at the time of the most recent interviews (1960), consisted of:—

Sir Frederick Brundrett (*Chairman*)	Civil Service Commission.
Sir Basil Schonland	Atomic Energy Authority.
Sir William Slater	Agricultural Research Council.
Dr. R. v. d. R. Woolley	Royal Greenwich Observatory.
Sir Harry Melville	Departmental of Scientific and Industrial Research.
Sir Graham Sutton	Meteorological Office.
Professor C. H. Waddington ...	Institute of Animal Genetics, Edinburgh.
Sir Robert Cockburn	Ministry of Aviation.
Sir Steuart Mitchell	Ministry of Aviation.

The Sub-Committee considers candidates put forward by Departments once a year. Over the last seven years the Sub-Committee has considered 203 candidates and recommended 141 special merit promotions; of this total 104 were to S.P.S.O., 35 were to D.S.C.O., and 2 were to Chief Scientific Officer.

11. When the Sub-Committee was first set up, the Agricultural Research Council and the Atomic Energy Authority were invited to use the scheme for their own staff. This they agreed to do. Later the Development Commission and the National Agricultural Advisory Service also joined the scheme. The Sub-Committee has itself maintained a distinction between these organisations and Government Departments proper, insofar as, while it regards itself as responsible for recommending promotions in respect of the Government Departments, it merely endorses (or otherwise) promotions recommended by the other organisations.

12. In putting forward candidates for promotion under the scheme, the sponsoring organisation provides a memorandum giving an account of the candidate's career and academic achievements, an account of his work, a list of his publications (including those which are purely departmental), and a list of possible referees (and references which have already been obtained either from the candidate's superior officers or from referees outside the Government Service). The Sub-Committee generally aproaches further referees of its own choosing, in particular specialists in the subject in which the candidate has done his work; these are, very often, from the universities. The Sub-Committee holds three meetings each year to discuss the candidates on the basis of the written information available before the candidates themselves are interviewed.

13. The Sub-Committee submits its recommendations each year, via the Inter-departmental Scientific Panel, to the Treasury; in practice its recommendations have always been accepted.

APPENDIX IX

RESEARCH FELLOWSHIPS

1. Research fellowships in certain Government scientific establishments have been offered since 1947. The scheme began in a small way at the Atomic Energy Research Establishment and certain other establishments then the responsibility of the Ministry of Supply. It was extended to all Departments in 1953. (The Atomic Energy Authority now runs its own scheme in parallel with the Civil Service scheme.)

2. The objects are

(i) to attract outstanding young scientists to work for a few years in Government research establishments, giving them some freedom in their research work, and terms of service which do not bind them to a civil service career;

(ii) to attract into the permanent service a proportion of those who accept fellowships.

3. The special conditions of the research fellowship scheme may be summarised as follows:—

(*a*) *Qualifications*. Candidates must have a good first or second class honours degree in science and must show evidence of a high standard of ability in research. There are no age limits; but a senior fellowship is only awarded to a man with at least three years' post-graduate research experience, and a junior fellowship to a man with at least two years' experience. The standard of selection is high; recruitment is through the Civil Service Commission, who hold several interview boards each year.

(*b*) *Pay*. Salaries are fixed by reference both to the current Scientific Officer/Senior Scientific Officer scales, and by reference to university salaries. They are now:

Senior Research Fellows—£1,325—£1,650
Junior Research Fellows— £910—£1,220

There are no annual increments; the Civil Service Commission recommend the appropriate figure within the bracket at the time of appointment.

(*c*) *Duration*. Fellowships are tenable for three years only, but those who have held fellowships can apply again. Fellows are given pension arrangements under the Federated Superannuation System for Universities.

Each year Departments tell the Civil Service Commission what research projects they have to offer for fellowships, and the Commission try to find suitable people. There are always more projects than suitable candidates; but Departments have to get formal Treasury authority for the numbers of research fellows they appoint, which are additional to the normal scientific complement.

4. Candidates for fellowships who are not up to the very high standard required are often offered S.O. or S.S.O. posts; a small number are recruited in this way each year. Since 1955, about three fellows each year have become established civil servants on the completion of their three years' fellowship; this is about a quarter of all fellows.

5. The following table gives the numbers of fellowships offered and taken up in the last five years:

Year	*Total Fellowships offered*	*Fellowships accepted and taken up*		
		Sen.	*Jun.*	*Total*
1955	31	7	6	13
1956	36	7	12	19
1957	51	11	5	16
1958	60	2	4	6
1959	82	14	13	27
1960	81	12	12	24

(The 1960 competition is still not finished; and a few more fellowships may be offered and accepted.)

(22) Wt. 3267 K24 12/61 St.S.